KEEPING OUR EYES OPEN: CONDUCTING AERIAL RECONNAISSANCE WITHOUT SPACE

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APPROVAL

The undersigned certify that this thesis meets master's-level standards or research, argumentation, and expression.

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DISCLAIMER

ABOUT THE AUTHOR

Squadron Leader Laroche is a Royal Australian Air Force pilot. After completing Pilot's Course in 1999, he was posted to 32 Squadron at RAAF East Sale where he qualified as HS748 Aircraft Pilot. During a five year posting at 32 Squadron, Squadron Leader Laroche achieved a variety of multirole qualifications including Air Lift, VIP, Formation and Check Captaincy. In 2003 he was selected to re-role onto the AP-3C Orion Maritime Patrol Aircraft. During a five-year tour at 11 Squadron and 92 Wing, Squadron Leader Laroche deployed extensively in support of border protection and the preservation of regional security and stability in South East Asia, including the North Indian Ocean and South China Sea. During this period, he also deployed three times to the Middle East conducting maritime patrol and overland ISR in as part of the Australian support for Operation Iraqi Freedom (OIF).

Promoted to Squadron Leader in 2008, Laroche completed a staff tour at the Directorate of Aviation and Air Force safety, before returning to the AP-3C as a flight commander. Whilst at 10 Squadron, Squadron Leader Laroche deployed again the Middle East in 2012 as commander of deployed Orion aircraft conducting ISR operations as part of the Australian support to Operation Enduring Freedom (OEF, and counter-piracy operations in regional waters. In April 2014 Squadron Leader Laroche assisted in the command of a multinational search effort for missing airliner MH-370 based on the west coast of Australia, before arriving in the United States in May to attend USAF Air Command and Staff College in 2014/15, and USAF School of Advanced Air and Space Studies in 2015/16.

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ABSTRACT

Aerial reconnaissance is a fundamental tool of national security, and an absolute necessity for the modern military commander. Access to space-based communications, position and timing technology has shaped the form and function of modern aerial reconnaissance, but has also created a dependency on space that makes the enterprise extremely vulnerable. This study critically analyzes how western powers might continue to conduct aerial reconnaissance in an environment where space-based assets are either degraded, denied or destroyed.

To answer this dilemma, the first half of this study makes the case that aerial reconnaissance in the western world not only has an increasingly functional dependence on space-based assets but that those assets are genuinely vulnerable. The second half of the study analyses the conduct of Western military aerial reconnaissance across three distinct periods of development: early adoption through to the end of WWII, post-WWII through to the end of the Cold War era, and the post-Gulf War era of increasing space dependence. Common trends and valuable insights are drawn from each of these periods in search of solutions for the current issue of space-dependent aerial reconnaissance.

The study concludes that not only will aerial reconnaissance remain critical to national security for the foreseeable future, but there are several lessons of the past 100 years that should be heeded as we move forward. There is no guarantee that Western access to space will definitely be compromised, nor that the US and allies should cease capitalizing on the advantages it provides them. That said, there is mounting evidence that the United States and its allies should prepare far more thoroughly for the possibility of needing to conduct aerial reconnaissance in a space denied environment.

The United States and its allies have consistently demonstrated the ability to provide aerial reconnaissance through adverse conditions and unforeseen scenarios, however, this last minute approach often comes at a significant cost to national blood and treasure. In order to be prepared for a space-denied scenario, leaders in the aerial reconnaissance field must not only acknowledge and discuss the dangers of relying too heavily on space-based assets, but work pro-actively to develop alternative methods of continuing the mission. Cross-domain stake-holders domains must encourage open dialogue in order to adequately prepare, identify suitable redundancy and develop technical solutions that will mitigate the vulnerabilities of space-based assets.

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Introduction

The idea for this paper evolved not from a glimpse of possibility, rather from an overwhelming feeling of vulnerability, that seemed to be creeping into the military environment in which I have spent the past two decades. Learning to fly and navigate on the Pilatus PC-9, was an experience in raw aviation - navigating by paper map strapped to your knee and using the 'Mark I eyeball' is about as redundant as technology gets, provided you don't lose your map on the way to the aircraft. From there I flew the venerable HS-748, a British designed twin engine turboprop that was best described as 13,000 rivets flying in close formation. With inertial navigation systems, analogue radios and analogue navigation aids, the basic design of the aircraft had proven reliable, flying VIPs around the country and overseas (and later teaching navigators how to navigate) since its introduction to the Royal Australian Air Force (RAAF) in 1968.

It was not until I converted to the newly upgraded AP-3C Orion Maritime Patrol Aircraft in 2003 that I first had an experience with the technologies that for many had been common place over the previous decade. Perhaps it was my extended period with the 'old' way of flying that made me more acute to the pros and cons technology was bringing with it. Like most projects, the upgrade of the P-3C to the AP-3C in 2001 was not without its teething problems and I was in a front row seat to see many of them (literally). My point here is not to air the specifics of those grievances, rather to illustrate how an upgrade that introduces new capability may also introduce vulnerabilities that previously did not exist. One such addition to the AP-3C was the introduction of Global Positioning Satellite (GPS) equipment into the heart of the aircraft. This indispensable navigation and timing tool is now so ubiquitous that we barely think twice about our phones, cars and pizza delivery apps using

the technology.[1] Not being able to track your pizza every 15 seconds might be an issue on game night, but it's thankfully not going to weaken national security. On the other hand, as I learnt in 2003, not receiving a GPS signal can be a mission ending scenario for an aircraft (and by extension, a capability) that only a few years earlier could perform precisely the same mission without it. Even in the early 2000s it was rare for GPS to be a problem, almost always down to operator error or set malfunction, though there were occasions where the environment simply precluded an accurate signal and left us without many options.[2] I started to wonder how many steps we were taking forward with this technology, and how many backward.

As I deployed to the Middle East for the third time in 2007, three more observations were becoming abundantly clear. First, the demand for Intelligence, Surveillance and Reconnaissance (ISR) was extraordinary and seem to increase every month. Second, our reliance on space-based assets to conduct our aerial reconnaissance mission had also dramatically increased since 2003. Finally, many units found they did not control or really understand the space-based assets they were using, and, when they were not available for any given reason, chaos normally ensued. Like many people focused on the tactical and operational level of conflict, I put this down to introductory problems with new technology and something that could be overcome with enough resources.

It was not until I came to study at Air University with the United States Air Force (USAF) that I became more aware of the vulnerabilities that currently exist to military space-based assets used by the five eyes (FVEY) community, not to mention the civilian sector which often carries the load of being dual use for both commercial and military

[1] Marianne Kolbasuk McGee, "GPS Comes To High-Tech Pizza-Delivery Tracking," InformationWeek, 2008. http://www.informationweek.com/gps-comes-to-high-tech-pizza-delivery-tracking/d/d-id/1064076? (accessed 25 January 2016)
[2] Volpe National Transportation Systems Center, "Vulnerability Assessment of the Transportation Infrastructure Relying on the Global Positioning System," (2001), 25.

communications.[3] Just like in 2003, I started to wonder if the cost of advantages gained by this new capability, space-based assets, had actually introduced a critical single point of failure into the system we were not prepared to handle.

At this point I should clarify that I am not a Luddite, nor is this paper about returning to steam power gauges and chalk on a whiteboard. As a child of the 1970s and 80s, I grew up with and fully embraced the computer age, so much so that I have learnt and re-learnt the lessons of early adoption and lack of redundancy more times that I care to recall. So too is the allure of technology strong in everyday western society, as well as in our militaries. Aviation, born from a consistent pursuit of technology and wonder, is particularly susceptible to the draw of attractive new technology that offers expanded capability. In the past three decades, it is hard to think of another area of progress that has offered more to boost the overall capability of air power than space-based assets. Wherever you may be, satellites can help you communicate. Wherever you wish to strike, satellites can help you do it with precision. Wherever you may wish to hide, satellites will help find you. After the first Gulf War when USAF General Merrill McPeak described Desert Storm as "the first space war", he was of course referring to the awesome capability boost it provided the allied warfighter with respect to communication, situational awareness, and detection.[4]

This paper affirms the continuing importance of aerial reconnaissance to national security, and determines some guidelines for how it might continue to be performed should the space-based assets on which it currently depends become denied or degraded. The first chapter clarifies terms and establishes the ongoing criticality of aerial

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[3] Five eyes refers to the intelligence sharing arrangements between Australia, Canada, New Zealand, the United Kingdom and the United States.

[4] Benjamin S Lambeth, "The Synergy of Air and Space," *Air & Space Power Journal* 12, no. 2 (1998).

reconnaissance to a wide range of consumers, from the battlefield or theatre commander to the strategist and the statesman. The second chapter will explore the threats to space-based assets, and their effects on aerial reconnaissance capability. Avenues for mitigating the risk are explored and evaluated. The conflation of space vulnerability and the continued desire for aerial reconnaissance raises a number of questions. Primary amongst them must be: how can we in the West meet the reconnaissance demands of our political leaders and battlefield commanders if access to space-based assets are lost or severely degraded? Chapters 3 and 4 attempt to address this question directly by studying examples of aerial reconnaissance from a period before the integration of space-based assets changed expectations and capability - for better and for worse. Finally, the study concludes with a summary of insights gleaned from historical analysis, as well as a set of guiding questions which should ideally be considered as we continue forward into uncertainty.

Chapter 1

Aerial Reconnaissance: An Overview

These first two chapters will discuss two areas that serve to frame this project's analysis of aerial reconnaissance and its space dependence. They will also add important context to the historical review in the latter half of the paper. Chapter one covers the limitations and assumptions of this study, as well as the terminology used to discuss aerial reconnaissance spanning the past 100 years. This is achieved by reviewing contemporary ideas on what constitutes ISR, and how reconnaissance fits that modern interpretation as well as offering my own definitions of the concepts discussed within this paper. The second chapter, critical to an underlying assumption of this project, analyzes western military reliance on space-based assets. This reliance exists in physical infrastructure and capabilities as well as much of western doctrine. The chapter concludes with a summary of the contemporary threats to space-based assets.

Limitations and Assumptions

The first and most controversial assumption made in this paper is that we should even be discussing operations in an environment where access to space based assets are either degraded or completely denied. For some this may seem overly alarmist or an assumption that is impossible to justify without specific context. For others, particularly those involved in the space enterprise, this assertion is not only obvious, but accepted at the highest level as a real and present danger.[5] There is

[5] Marcus Weisgerber, "The Air Force's Next Chief Might Be Its Space-War General," Washington, DC: Atlantic Media Company, 2016. http://www.defenseone.com/management/2016/04/air-force-general-space-war-chief/127437/. (accessed 23 May 2016)

a growing mass of literature discussing the complicated issues of potential and actual space conflict, as well as the many indirect threats that exist to space-based assets. While the threats to space-based assets are more widely acknowledged and accepted now, discussion on what to do after an event or series of events has led to the loss of access to space-based assets is noticeably absent. There are increasing signals both domestically and internationally that a space denied environment is not only possible, but due to the increasing reliance on space-based assets is ever more probable. While this paper cannot determine the exact probability of such events occurring, the assumption is that they are increasingly likely and therefore worth our concern and preparation.

Should an attack or event occur that affected western space-based assets, capability will be degraded to a greater or lesser degree depending on a broad range of factors. In a kinetic conflict for example, the sanctity of space and its orbits may quickly become a debris field rendering assets unusable and, in time, denying all space-based ISR. Even without conflict there is speculation that the increased use of space is creating debris at a rate that may eventually make low Earth orbit (LEO) unusable.[6] On the other hand, perhaps those nations or actors capable of creating such chaos in space may show restraint or be deterred sufficiently that they choose to never execute the option. Either way, the prudent assumption, and one made in this study, is to at least plan for those assets not being available 'right of bang'.[7] The issue of probability of potential space conflict is addressed in due course, but as this topic has the potential to alienate a percentage of this study's potential readership, it is prudent to address it.

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[6] Peter L. Hays, *Space and Security: A Reference Handbook*, Contemporary world issues (Santa Barbara, Calif.: ABC-CLIO, 2011), 91.

[7] 'Right of bang' describes events after the first shot has been fired, or in this case, an event has occurred denying access to needed space-based assets.

A slight limitation of this paper is that it is written at the unclassified level. Readers who have access to or knowledge of some of the programs and capabilities discussed within this study may find themselves frustrated at the coarse descriptions of their particular field of expertise. Despite this hurdle, the decision to keep this paper accessible is in the interest of cultivating the discussion of space vulnerability and potential solutions at all levels. While this is not the first or most detailed study to look at space-based asset vulnerability, it is another voice in a growing crowd of concern over how to deal with it. The current chasm between our military responsibilities, our dependence on space to achieve them, and our relative lack of ability to protect space will not disappear without continued discussion of the topic. The primary goal of this paper is to frame space vulnerability within the specific context of aerial reconnaissance, one of many predominately military capabilities that will remain critical at all levels of command and governance, whether at war or peace.

Even with a relatively narrow focus on aerial reconnaissance as a subset of ISR, it is impossible to address all the variants of airborne platforms with their myriad configurations within the scope of this work, although the pursuit would make for beneficial future research. Where appropriate, this paper references specific platforms or capabilities, but the intent is not to perform a technical analysis of a specific capability. Similarly, as this paper targets a broad audience, it will speak generally to the American experience of both space-based assets and aerial reconnaissance, with side references to other FVEY countries as indicative of allied perspectives where appropriate.

The field of ISR, and reconnaissance in particular, extends well beyond the airborne, air-breathing, manned variants that are predominantly referred to in this paper, particularly in the historical analysis. While this study may not highlight them specifically, there are certain ISR commonalities that exist regardless of platform, structure, or

domain. Indeed, the same contemporary reliance on space-based assets exists to varying degrees across other domains, be they airborne, surface, sub-surface or land based. While the lessons uncovered through this analysis will hopefully be of use in other fields, this paper will limit discussion of reconnaissance to the airborne variety, contrasting against alternatives where appropriate. In part this is because of the author's experience in this particular field, though predominately it is because in a space denied environment, manned airborne ISR remains extremely flexible, whilst returning some of the temporal advantage that space-based assets normally facilitate. The reference to *manned* airborne ISR is not intended to exclude platforms such as unmanned aerial vehicles, rather to suggest an element of human interaction, decision making, and interpretation. For instance, a UAV that has a reliable link to a crew of operators and analysts to be manned even though it is not occupied.

Reconnaissance Unpacked

This study will refer to several recurring terms throughout, some of which have subtly changed meaning over the past 90 years. For the sake of clarity, those terms are defined here.

Reconnaissance is fundamentally a task undertaken to obtain information about places, persons, or objects by visual observation or other means.[8] *Surveillance* is primarily different from *reconnaissance* in a temporal sense. While reconnaissance of a given target does not necessary need or imply persistence, surveillance requires a commitment

[8] A definition adapted from:
United States Department of Defence., "JP 2-0 Joint Intelligence," ed. Defense (Washington D.C.: DoD, 22 October 2013). "A mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy or adversary, or to secure data concerning the meteorological, hydrographic, or geographic characteristics of a particular area." and United Kingdom Ministry of Defence., "JDP 0-30 UK Air and Space Doctrine," ed. MoD (Shrivenham, England: The Development, Concepts and Doctrine Centre, 2013). "observation of aerospace, surface or sub-surface areas, places, persons or things, by visual, aural, electronic, photographic or other means."

of time in order to systematically observe the desired pattern, change, or trigger.[9] For the purposes of the problems and analysis put forth by this study, the terms *reconnaissance* and *surveillance* are effectively synonymous.

Aerial reconnaissance then, merely adds the addition of altitude to the equation, be it via fixed-wing, rotary wing, or lighter-than-air craft. The prefix of aerial does not typically include assets on orbit, therefore *satellite reconnaissance* describes reconnaissance from space. The combination of aerial and satellite reconnaissance is sometimes simply referred to as *overhead reconnaissance*.

More common in the modern lexicon is the term ISR which connects and groups the gaining *intelligence* from surveillance and reconnaissance activities. The concept of ISR as an integrated process has been with us now for around two decades, allegedly first used by former Vice Chairman of the Joint Chiefs of Staff, Admiral William Owens. In 1996 Owens described ISR as involving "sensor and reporting technologies associated with intelligence collection, surveillance, and reconnaissance, as well as the new means by which we are able to keep track of what our own forces are doing."[10] This first cut has survived the test of time reasonably well, though modern interpretations have placed additional emphasis on the post-collection activities of *processing*, *exploiting,* and *disseminating* (PED) this information. Because the military term ISR has entered the popular parlance of military members, politicians, academics and even the civilian sector, it is useful to see how contemporary military doctrine defines it.

In the United States, Joint Publication 1-02, the Department of Defense (DoD) dictionary of military terms, describes ISR as:

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[9] United States Department of Defence., "JP 2-0 Joint Intelligence," I-11.; United Kingdom Ministry of Defence., "JDP 0-30 UK Air and Space Doctrine," 3-8.
[10] William A Owens, "The Emerging US System-Of-Systems," (DTIC Document, 1996).

> An activity that synchronizes and integrates the planning and operation of sensors, assets, and processing, exploitation, and dissemination systems in direct support of current and future operations. This is an integrated intelligence and operations function.[11]

By contrast, the US Air Force prefers the following definition found in Air Force Defense Doctrine 2-9:

> The goal of ISR operations is to provide accurate, relevant, and timely intelligence to decision makers. The Air Force best achieves this goal through effective employment of ISR capabilities, and by capitalizing on the interoperability existing among our ISR systems, as well as non-traditional sources, to create synergy through integration.[12]

In the United Kingdom the Ministry of Defence Joint Doctrine on Air and Space:

> Activities that synchronise and integrate the planning and operation of collection capabilities, including the processing and dissemination of the resulting product.[13]

Canadian Aerospace doctrine:

> An activity that synchronizes and integrates the planning and operation of all collection capabilities with processing and dissemination of the resulting information to the right person, at the right time, in the right format, in support of current and future operations.[14]

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[11] United States Department of Defence., "JP 1-02 Dictionary of Military and Associated Terms," ed. Defense (Washington D.C.: DoD, 8 November 2010 (As Amended Through 15 February 2016)), 116.
[12] LeMay Center for Doctrine, "AFDD 2-9 Intelligence, Surveillance and Reconnaissance Operations," (Maxwell AFB, AL: United States Air Force, 2007), 1.
[13] United Kingdom Ministry of Defence., "JDP 2-00 Understanding and Intelligence Support to Joint Operations," ed. MoD (Shrivenham, England: The Development, Concepts and Doctrine Centre, 2011), 2-17.
[14] Royal Canadian Air Force, "B-GA-403-000/FP-001, Canadian Forces Aerospace Shape Doctrine," ed. Commander 1 Canadian Air Division (Winnipeg, Canada: Canadian Forces Aerospace Warfare Centre, 2014), 108.

An Australian take on ISR can be found in AAP 1001.3 *The Air Force Approach to ISR*:

> An activity that synchronises and integrates the planning and operation of sensors, assets, and processing, exploitation and dissemination systems in direct support of current and future operations.

The Australian case provides a recent example of the increasing intention to consider ISR as an entirely integrated and fused process from collection through to PED. In 2009, the Australian references to ISR spoke only of collection, but by 2011 the definition was changed to the one quoted above, and the surrounding explanation describes an interconnected and interdependent communication network allowing real-time data transfer between collectors and processors.[15]

The lesson gained from comparing perspectives of these aligned but still quite different nations is that regardless of structure, composition or size, ISR is seen today as being highly dependent on synchronized, integrated, and rapid transfer of relevant information to decision makers. Without question, the end product is intelligence, and the goal is for that intelligence to be both accessible and actionable. As we explore the historical examples throughout the second half of this paper, it will become clear that despite *aerial reconnaissance* lacking the moniker and detail of *ISR*, the goal is exactly the same. What has changed between the aerial reconnaissance of the past and ISR of today, is the speed, reach, and quantity of product that modern ISR techniques affords us. The developments in aerial reconnaissance are predominately linked to the West's unfettered and increasing access to space-based assets.

[15] Royal Australian Air Force, *The Air Force Approach to ISR / Royal Australian Air Force*, Australian Air Publication; AAP 1001.3 (Canberra, Australia: Air Power Development Centre, 2011), iii, 2-22.

Chapter 2

Space: Pros and Cons

The United States and its allies enjoy remarkable military and commercial advantage through the use of space-based assets. Satellites provide functions so ubiquitous in western society that we rarely stop to think about where they come from, how they are enabled, and what would happen if we lost them.[16]

Humanity as a whole has benefited from the myriad functions provided to us through the use of satellites. Beyond the military uses focused on in the paper, satellites have enhanced almost every aspect of our daily lives, including: television, telephones, navigation, business and finance, weather, climate and environmental monitoring, safety, land stewardship, development, and the further scientific understanding of space itself.[17]

Aviation in general has become increasingly dependent on space. As referenced in the introduction of this study, aircraft dependence on GPS for position, navigation, and timing (PNT) information has become almost absolute. In the United States for instance, the Federal Aviation Administration (FAA) is in the process of implementing Automatic Dependent Surveillance-Broadcast (ADS-B) which "is the satellite-based surveillance system that air traffic controllers are using now to monitor and safely separate aircraft."[18] In the current implementation of ADS-B,

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[16] Richard Hollingham, "What Would Happen If All Satellites Stopped Working?," BBC, 2013. http://www.bbc.com/future/story/20130609-the-day-without-satellites. (accessed 24 March 2016)

[17] A sample list of satellite uses borrowed from: Union of Concerned Scientists, "What Are Satellites Used For?," Union of Concerned Scientists. http://www.ucsusa.org/nuclear-weapons/space-weapons/what-are-satellites-used-for#.VypepWO7f8s. (accessed

[18] Federal Aviation Administration, "Fact Sheet – Automatic Dependent Surveillance-Broadcast (ADS-B)," 2014. http://www.faa.gov/news/fact_sheets/news_story.cfm?newsid=16874. (accessed 3 Feb 2016)

aircraft send their GPS-derived positional information to ground stations that automatically pass the information to controllers. Future upgrade plans to the ADS-B system will eventually move all steps of the communication process to satellites; therefore, satellites will be the source of an aircraft's position and timing, as well as the relay for that information to get to air traffic controllers and other aircraft. The aim of the system is to replace the current network of air traffic control radars and provide more consistent and complete coverage for national air traffic control. The exclusive reliance on space-based assets for a role as critical as air traffic control is of concern to some observers, as is the eventual decommissioning of the radar system that could at least provide some redundancy.[19]

Returning to aerial reconnaissance, the way western militaries implement much of the ISR process today involves an even deeper dependence on space than examples discussed above. Not only is satellite reconnaissance a significant part of the collection assets for the ISR process, but the delivery and security of other collection methods now also rely heavily on satellites for transmission throughout the PED process.[20] The aerial reconnaissance mission is more dependent on space than at any time in history, driven in part by the United States focusing on Global Integrated ISR as a matter of priority.[21] With an assumed requirement to operate globally, satellite communications (SATCOM) quickly become the most attractive and utilized medium. Airborne ISR assets operate remotely, often using 'reachback' capabilities via satellites to operators or the PED process back at home bases.[22]

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[19] Leon Purton, Hussein Abbass, and Sameer Alam, "Identification of ADS-B System Vulnerabilities and Threats" (paper presented at the Australian Transport Research Forum, Canberra, 2010).
[20] United States Department of Defence., "JP 2-0 Joint Intelligence," V-10.
[21] LeMay Center for Doctrine, "AFDD 2-0 Global Integrated Intelligence, Surveillance, & Reconnaissance Operations," (Maxwell AFB, AL: United States Air Force, 2012), 1.
[22] Doctrine, "AFDD 2-0 Global Integrated Intelligence, Surveillance, & Reconnaissance Operations," 7.

The enhanced capability that satellites provide is not in question, as the United States and partners have demonstrated many times since the Persian Gulf War in 1991. Elbridge Colby aptly summarizes the critical edge space provides in 2016:

> The United States is profoundly reliant on the ability to use space for its security. Though little appreciated outside of professional and expert circles, space – or, more precisely, U.S. assets in and using space – are vital to U.S. defense and intelligence communications with and among national leaders, military forces, and others; command and control; positioning, navigation, and timing (PNT); intelligence, surveillance, and reconnaissance (ISR); and a host of other functions. While these may seem rather like "back office" functions to a lay reader, they are actually the stuff of which American global military primacy is made. The U.S. military is not currently superior to its potential adversaries because it has stronger soldiers, bigger guns, or more tanks. Rather, it has the upper hand because it can understand better what is taking place in the midst of conflict, what its own forces are doing, and what those of an enemy are doing amidst the "fog of war."[23]

America and its allies should by now clearly understand not just the advantages of space as Colby summarizes, but the vulnerabilities that currently exist. Unfortunately, there is still significant rhetoric in our doctrine that promotes the advantages of space-based assets without acknowledging or planning for the vulnerabilities. An example can be found in current USAF Global Integrated ISR doctrine which cites an advantage of space-based ISR systems as being less vulnerable than terrestrial alternatives, but does not attempt to address disadvantages in any way: "The prime advantage of space-based systems is their global and wide-area coverage over denied areas where little or no data can be

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[23] Elbridge Colby, "From Sanctuary to Battlefield: A Framework for a U.S. Defense and Deterrence Strategy for Space," (Washington, DC2016), 4.

obtained from ground and airborne sources. Other advantages these systems possess include mission longevity and reduced vulnerability to adversary action."[24] Later in this study we will explore precisely why this is a disingenuous representation as we explore the vulnerabilities that exist in space-based systems.

The United States is not alone in both exploiting the advantages of space for reconnaissance, while simultaneously building a significant dependence on its continued availability for success. Australia's military literature expounds the many advantages of space while side stepping the critical question of how to assure it: "Access to space based ISR systems ensures the ADF has access to a combination of ISR systems to balance capability strengths and weaknesses across target types and operational environments."[25] This document, and many like it, fail to discuss or analyze the second- or third-order effects of relying so heavily on space-based ISR systems. The United Kingdom fairs a little better, acknowledging within core military doctrine that there is an extraordinary military dependence on access to space-based assets. This passage is contained within current *U.K. Air and Space Doctrine* and is based on testimony given by the Chief of Air Staff to the House of Commons as far back as 2007:

> The UK, like all modern states, depends on space services for everything from informing foreign policy decision-making down to day-to-day functions, such as enabling financial transactions and operating the power grid. About 90% of the UK's military capabilities depend on space, principally for communications and position, navigation and timing functions, but also for intelligence, surveillance and reconnaissance (ISR).[26]

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[24] LeMay Center for Doctrine, "AFDD 2-0 Global Integrated Intelligence, Surveillance, & Reconnaissance Operations - APPENDIX B: ISR RESOURCES," (Maxwell AFB, AL: United States Air Force, 2015).
[25] Royal Australian Air Force, 2-22.
[26] United Kingdom Ministry of Defence., "JDP 0-30 UK Air and Space Doctrine," 5-1.

Clearly the United States and its allies have built a considerable dependence on space for both the acquisition and execution of aerial reconnaissance and the greater ISR process. It is understandable why this occurred; since the end of World War II, the United States has a much larger self-imposed area of global responsibility compared to any other nation. Furthermore, the United States has found itself with far and away the preponderance of investment and assets in the space environment.[27] Having established that the western militaries' aerial reconnaissance function, amongst many others, relies extensively on access to space-based assets, the major question left unanswered is: what are the vulnerabilities that exist to that capability? The answer to that question lies in the next section.

Holes in space

Admiral Owens may have coined the term ISR back in 1996, but just as interesting is what he notes later in his system-of-systems pitch for Strategic Forum (italics for emphasis):

> There is, to be sure, great danger in relying on military systems that have exploitable flaws. Indeed, the characteristic that gives any system its potency-that the parts of a system enhance the effectiveness of one another-also makes them susceptible to catastrophic failure if one of their central parts can be corrupted. Yet there are some aspects of the system-of-systems that ought to alleviate, if not refute, these concerns. First, the people implementing the vision are far from ignorant of the danger of *inherent flaws*. A great deal of thought, planning, money, and continual effort goes into reducing *real or hypothetical vulnerability*. We won't wait until someone else finds a vulnerability; we will think and work continually to find and *eliminate it first*.

[27] School of Advanced Air & Space Studies - Class 665: *Space Power*.

> Second, the computer and communications technologies on which the system-of-systems are based are *becoming less, not more, susceptible* to the various forms of corruption and interference. A race will always exist between those who try to ensure the security of information-based systems and those who seek to overcome their security measures. Yet, the trend favors the defense. In part, this is because of the relative "hardness" of the new generations of communications equipment. Fiber optic cable, for example, has physical characteristics that make it inherently more difficult to "tap" surreptitiously.[28]

Owen's observation on the vulnerability of interdependent systems holds true today and is particularly applicable when applied to our growing dependency on space. With the benefit of 20 years of hindsight, we now know that while computers and communications did continually improve their security, the reduced cost of entry precipitated by the information age has also brought a rapid increase in the number of people fighting to defeat that security.[29] In the space field specifically, there are many people working on the problems of space vulnerability, but the idea that these technologies would become "less, not more, susceptible" to interference has not exactly eventuated in the way the Admiral thought it would 20 years ago.[30] This section will discuss the various threats that currently exist to space based-assets, as well as some of the mitigations and defense mechanisms designed to defeat the threat.

It is important to note that there are several components that make up typical space operations, all of which are necessary for the

[28] Owens, "The Emerging US System-Of-Systems."
[29] Richard A. Clarke and Robert K. Knake, *Cyber War: The Next Threat to National Security and What To Do About It,* 1st Ecco pbk. ed. (New York: Ecco, 2012), 104.
[30] For instance, DARPA is working on projects such a GPS alternative known as ANS: Lin Haas, "Adaptable Navigation Systems (ANS)," DARPA. http://www.darpa.mil/program/adaptable-navigation-systems. (accessed 18 May 2016). Satellite hardening options, while expensive,

successful transmission of communication to and from space. U.S Department of Defense refers to these as segments.[31] Broadly, these segments include ground, space, data link, and user. When we discuss the vulnerabilities of space assets, we must include all parts of the system, not just the anti-satellite (ASAT) capabilities that often receive most of the focus.

Jamming

A satellite's signal must transmit unobstructed from the satellite to another destination in order to be useful, usually a ground station on Earth. The data link between the space segment and ground segment is known as a downlink. Similarly, an uplink is any signal that is broadcast from a ground segment to a space segment, typically a satellite.[32] Interrupting the data link with excessive noise on the same frequency or series of frequencies is known as jamming, and in a lot of cases can be relatively cheap and easy to implement.[33] A more difficult variant is spoofing, which fakes a signal at the same frequency and power level as the original in order to create confusion.[34]

The U.S. military claims to have certain communications satellites that are 'protected' and resist jamming by using techniques such as narrow beamwidths and frequency hopping. Whilst these make jamming or spoofing much harder, they are also limited resources that are reserved for "the most critical strategic forces and C2 systems".[35]

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[31] Department of Defence., "JP 3-14 Space Operations," ed. Defense (Wshington D.C.: DoD, 29 May 2013), II-2.
[32] Department of Defence., "JP 3-14 Space Operations," D-1.
[33] Infosec Institute, "Hacking Satellites … Look Up to the Sky," 2013. http://resources.infosecinstitute.com/hacking-satellite-look-up-to-the-sky/. (accessed 24 March 2016)
[34] David Wright, Laura Grego, and Lisbeth Gronlund, "The Physics of Space Security," *A Reference Manual. Cambridge: American Academy of Arts and Sciences* (2005): 119.
[35] Department of Defence., "JP 3-14 Space Operations," D-4.; Sydney J. Freedberg, "US Can't 'Stick Our Heads In The Sand' On Space Threats: Gen. Shelton," Breaking Defense, 2014. http://breakingdefense.com/2014/07/us-cant-stick-our-heads-in-the-sand-over-rising-threats-to-space-gen-shelton/. (accessed 23 March 2016)

Dazzling

Similar to jamming, dazzling uses lasers to temporarily prevent a satellite's sensors from acquiring images. This generally requires the laser to be on the ground in the area the satellite is trying to image, and the technique is reasonably complex because it requires the laser to operate at the frequency bands and wavelengths of the satellite's various filters.[36] Because a laser can typically occupy only a fraction of the satellite's field of view, it would not stop the satellite collecting imagery completely, rather just in a particular area. Nonetheless, dazzling remains a viable option that is difficult if not impossible to defend against.[37]

Partial Blinding

At a high enough intensity, a laser may permanently damage a satellite's sensors.[38] The same limitations as dazzling apply: the laser must be in the sensor's field of view and it will only affect a few pixels of the satellites sensor at a time. Because the damage is permanent, however, adversaries could use this technique to gradually degrade a satellite's sensor to an unusable degree.[39]

High Power Microwaves (HPM) Attacks

This form of directed-energy attack could be launched from either a ground-based or space-based platform, and with high enough energy, could cause permanent damage to a satellite and its components.[40] The technology used for HPM has been maturing in recent years, and the

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[36] Wright, Grego, and Gronlund, "The Physics of Space Security," 128.
[37] "NRO Confirms Chinese Laser Test Illuminated U.S. Spacecraft," 2006. http://spacenews.com/nro-confirms-chinese-laser-test-illuminated-us-spacecraft/. (accessed 11 Feb 2016)
[38] Wright, Grego, and Gronlund, "The Physics of Space Security," 128.
[39] Wright, Grego, and Gronlund, "The Physics of Space Security," 129.
[40] Wright, Grego, and Gronlund, "The Physics of Space Security," 130.

USAF is reportedly investing in its development for use in advanced missile projects.[41] While unproven in the space domain, the development of this technology as a weapon does threaten the majority of satellites on orbit or in design without the appropriate hardening.

Laser Attacks

Unlike dazzling or blinding, the intent of this attack is to use the high energy of the laser to heat a satellite up to the point of failure and potential structural damage.[42] These attacks can come from any angle because they are not targeted at a specific sensor on the satellite. The power of the laser determines the effectiveness of the attack and is the main limiting factor.[43] Building a laser big enough to operate from Earth requires advance manufacturing capabilities, but is not outside the realm of possibility for future potential adversaries of the United States or its allies. Alternatively, many small lasers could be used in a combined attack if the accuracy were sufficiently high. "Studies of laser attacks on satellites estimate that for unshielded satellites in low earth orbits, ground-based megawatt class lasers could create this damage in a few seconds, and for the most fragile parts, kilowatt-class lasers could do the same in a longer period of time. Laser attacks intended to disrupt the satellite by heating may require lower power. The altitude of geostationary satellites protects them from structural damage by lasers on the ground or in low earth orbits."[44]

[41] Tamir Eshel, "US Air Force Moves Forward with High-Power Microwave Weapon," Defense Update, 2015. http://defense-update.com/20150516_champ.html. (accessed 23 March 2016)
[42] Wright, Grego, and Gronlund, "The Physics of Space Security," 134.
[43] Wright, Grego, and Gronlund, "The Physics of Space Security," 134.
[44] Wright, Grego, and Gronlund, "The Physics of Space Security," 134.

Ground Station Attack

As critical as the satellite itself is to the flow of information, it relies enormously on ground stations to provide maintenance, maneuver, and instruction.[45] Physical security and intelligence monitoring reduce the risk of attack to military ground station installations, and, since they exist in areas of sovereign territory, an adversary would be making a considerable statement by targeting them.[46] This does not rule out the risk completely of course, particularly if conflict is already underway or if a non-state actor becomes involved. Coupled with the continued threat of low cost cyber attacks, ground stations may become an important target for an adversary looking to reduce the asymmetric space power advantage enjoyed by the United States and its allies.

Generally military ground stations are designed to have multiple redundant facilities, which limits the effectiveness of using this attack vector, but the same cannot always be said for civilian satellite control stations.[47] When combined with one or two of the other satellite threats covered here, ground station attacks may create enough of a problem to prevent space operators from defeating other attack vectors.

Kinetic Energy (KE) Attacks

Satellites move extremely fast when on orbit, such that collision with another physical object can create a significant amount of damage or could cause the satellite to tumble out of orbit.[48] A kinetic attack is any attack that attempts to physically move, damage, or destroy a satellite. In January of 2007, the People's Republic of China successfully

[45] Department of Defence., "JP 3-14 Space Operations," V6-7.
[46] Forrest E. Morgan and Project Air Force (U.S.), *Deterrence and First-Strike Stability in Space: A Preliminary Assessment*, RAND Corporation monograph series (Santa Monica, CA: RAND, 2010), 14.
[47] Mike Gruss, "Report Cites Vulnerability in NOAA's Satellite Ground Stations," 2014. http://spacenews.com/41685report-cites-vulnerability-in-noaas-satellite-ground-stations/. (accessed 20 May 2016)
[48] Wright, Grego, and Gronlund, "The Physics of Space Security," 135.

tested a kinetic anti-satellite weapon against an aging Chinese satellite.[49] Further ASAT missile testing occurred in 2014, though without physical contact and resultant debris.[50] China joins the United States and Russia as having demonstrated the ability to perform KE-ASAT.

The resulting debris from a kinetic attack such as the one discussed above creates a debris field that remains in orbit for many years. Concerns over what was seen as irresponsible international behavior arose from fears that the weaponization of space may inevitably lead to the Kessler Syndrome and the complete loss of lower earth orbit for decades if not longer.[51] The Kessler Syndrome describes a cascading sequence of collisions on orbit where the debris from each collision spreads out and in turn causes more collisions with other satellites.

High Altitude Nuclear Detonations (HAND)

In the late 1950s and early 1960s both the United States and the Soviet Union experimented with high altitude nuclear detonations in space. The United States detonated several devices between 1958 and 1962, culminating with Starfish Prime, detonated below what we now call Lower Earth Orbit (LEO).[52]

> The test produced a visual extravaganza as well as several unintended effects that reverberated in Washington. The nuclear blast knocked out electrical systems throughout Hawaii — 715 miles away. More importantly, electromagnetic pulse (EMP) effects from the blast seriously damaged the solar panels of three orbiting satellites even though they were not in the line-

[49] Hays, 93.
[50] Colin Clark, "Chinese ASAT Test Was 'Successful:' Lt. Gen. Raymond," Breaking Defense, 2015. http://breakingdefense.com/2015/04/chinese-asat-test-was-successful-lt-gen-raymond/. (accessed 17 Feb 2016)
[51] Michelle La Vone, "Kessler Syndrome," Space Safety Magazine, 2014. http://www.spacesafetymagazine.com/space-debris/kessler-syndrome/. (accessed 28 January 2016)
[52] Clayton K. S. Chun, *Shooting Down a Star: Program 437, the US Nuclear ASAT System and Present-day Copycat Killers*, CADRE paper (Maxwell Air Force Base, Ala.: Air University Press, 2000), 3.

> of-sight of the nuclear detonation. The radiation effects lingered in the earth's magnetic fields and affected satellites that followed an orbital path through the detonation area. Electronic components were destroyed and continued exposure to radiation trapped in the Earth's magnetic fields degraded the life of affected satellites. The damaged satellites included two classified Air Force satellites and Ariel, a joint British-US satellite.[53]

Today it is possible to harden LEO satellites against the kind of radiation that a nuclear detonation would yield, but it has not been a priority for the hundreds of currently deployed satellites. Peter Hays estimates that it may take as little as one detonation to disable all non-hardened LEO satellites and hundreds of billions of dollars to replace them.[54]

Peter Pry, an expert on Electromagnetic Pulse (EMP) and executive director of the Task Force on National and Homeland Security, believes North Korea may be close or already has the ability to strike the United States with a 'Super-EMP' from a satellite.[55] While the credibility of this claim may be in question, the technology and knowledge required to create such a weapon is not.

Although weapons of mass destruction are currently banned from orbit by the Outer Space Treaty of 1967, a state facing regime change or collapse may be tempted to utilize a nuclear weapon in this manner for maximum effect.

Cyber Attacks

Satellites, like most modern electronics, contain computer hardware that runs software and firmware. Commensurate with the rest

[53] Chun, 4.
[54] Hays, 88.
[55] Paul Bedard, "Expert: North Korea's H-bomb is 'Super-EMP' Weapon," *Washington Examiner*, January 6, 2016.

of the cyber domain, wherever there is software to exploit someone will try to brute force a hack, open a backdoor, insert a trojan or otherwise interfere with normal operations for gain or grief.[56] IOActive, an American based security firm, published a technical white paper in 2014 that highlights vulnerabilities found in the software or firmware of several ground station devices. The report found "that all devices within the scope of this research could be abused by a malicious actor. The vulnerabilities we uncovered what would appear to be multiple backdoors, hardcoded credentials, undocumented and/or insecure protocols, and weak encryption algorithms. These vulnerabilities allow remote, unauthenticated attackers to compromise the affected products."[57]

Space Weather

So far all of the vulnerabilities of space-based assets have been man-made, but potentially the most devastating threat comes from nature. In 1859 a huge solar flare erupted on the surface of the sun that was so significant it was observed and recorded by English Astronomer Richard Carrington. This event, known later as the Carrington event, was so large "telegraph systems worldwide went haywire. Spark discharges shocked telegraph operators and set the telegraph paper on fire. Even when telegraphers disconnected the batteries powering the lines, aurora-induced electric currents in the wires still allowed messages to be transmitted."[58]

In a 2005 NASA study on the impact of another Carrington event, researchers concluded: "All indications point to a potentially major

[56] Jason Healey, *A Fierce Domain: Conflict in Cyberspace, 1986 to 2012* (Vienna, VA: Cyber Conflict Studies Association, 2013).; Ellen Nakashima, "Russian Hacker Group Exploits Satellites to Steal Data, Hide Tracks," *The Washington Post*, 9 September 2015.
[57] Ruben Santamarta, "A Wake-Up Call for SATCOM Security," in *IO Active* (2014).
[58] Trudy E. Bell and Dr. Tony Phillips, "A Super Solar Flare," NASA, 2008. http://science.nasa.gov/science-news/science-at-nasa/2008/06may_carringtonflare/. (accessed 10 Feb 2016)

economic and military impact of our space assets for the next major 1859-like superstorm event. Unlike previous historical events, our current reliance on satellite technology and human activities in space, place us in a unique and unprecedented nexus of vulnerabilities from such an event."[59] Forecasting this type of event is almost impossible, and even advanced warning may not come with enough time to make a meaningful difference to defensive preparations.[60]

Summarizing the Space Dilemma

Some readers may rationalize the concerns discussed above by citing the arguably low probability of their occurrence, thus making the decision to plan for their eventuality a low priority. There is enough evidentiary literature to suggest the probabilities are not particularly low. James March makes an even more convincing observation, however, in his primer on decision making: "When planning scenarios exclude extremely unlikely events, they tend to overlook (1) that many of these unlikely events would have very substantial consequences if they were to occur, and (2) that although each one of these events is extremely unlikely to occur, the chance of none of them occurring is effectively zero."[61]

Attempting to mitigate the vulnerabilities of space assets is a continual challenge for the space community and one that is receiving a great deal of attention.[62] There are currently very real limitations to achieving the reduction of space asset vulnerability whether through

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[59] Sten Odenwald, James Green, and William Taylor, "Forecasting the Impact of an 1859-Calibre Superstorm on Satellite Resources," *Advances in Space Research* 38, no. 2 (2006): 27.
[60] Odenwald, Green, and Taylor, "Forecasting the Impact of an 1859-Calibre Superstorm on Satellite Resources," 25.
[61] James G. March and Chip Heath, *A Primer on Decision Making: How Decisions Happen* (New York
Toronto: Free Press, 1994), 48.
[62] General John Hyten, interview by David Martin2015,http://www.cbsnews.com/news/rare-look-at-space-command-satellite-defense-60-minutes/.

improved technology, diplomacy, or deterrence. These challenges must be met and the security of space become far more predictable, but the dearth of credible solutions suggests we should also be thinking of alternative ways to assure critical strategic reconnaissance capabilities. To practitioners and consumers of aerial reconnaissance, we must accept that the demand for this product, specifically the intelligence it generates, will not disappear if space assets were to become denied, degraded, or destroyed. In such a scenario, it is reasonable to assume the demand for aerial reconnaissance sourced intel would actually increase.

Aerial reconnaissance may be a subset of the broader ISR complex, but it is one that remains of critical import to the national security of the United States and its allies. The next section will revisit aerial reconnaissance over the past century highlighting the importance of the field to statesmen and commanders, as well as extracting insights and trends that are transferrable to the problem posed in this paper. For historians of this era, these vignettes will offer little in the way of revelatory exposure. If, however, this paper begins to unite two fields of study in search of a solution to this most pressing strategic issue, it will be a success. I proposed at the outset of this paper that there are valuable lessons to be extracted from the 80+ years of aerial reconnaissance experience we developed prior to satellite dependence. Chapters 2 and 3 will test that hypothesis.

Chapter 3

Aerial Reconnaissance In Two World Wars

In the 30 years between 1914 and 1945, aerial reconnaissance went from an untrusted novelty to a war winning necessity. This chapter will trace the evolution of aerial reconnaissance from the 19th century through to 1945, focusing on three distinct periods — World War One, the interwar period , and World War Two. The discussion is focused on how aerial reconnaissance was developed, conducted, and utilized in an age before satellites, and what lessons are applicable to the contemporary dilemma of conducting aerial reconnaissance in a space denied environment.

From Versailles to Hell and Back Again

In the centuries preceding WWI, mankind dreamt of what it must look like to observe the Earth from above.[63] Throughout the 19th century, the advent of the balloon began to make the dream of achieving a bird's eye view a reality. In fact, the first attempts to carry passengers occurred in 1783 after the French brothers Montgolfier impressed the royalty and crowds gathered at Versailles.[64]

A few visionaries of the time recognized the potential for military application of the balloon. In post-revolution France, the French military attempted limited signaling and reconnaissance through to the end of the 18th century, even going as far as to form a Ballooning Corps.[65] In 1799 however, Napoleon closed down the ballooning corps after his failed

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[63] Beaumont Newhall, *Airborne Camera: The World From the Air and Outer Space* (New York: Hastings House, 1969), 11.
[64] A. Hildebrandt and W. H. Story, *Airships Past and Present: Together With Chapters on The Use of Balloons In Connection With Meteorology, Photography and the Carrier Pigeon* (London,: A. Constable & Co. ltd., 1908), 13.
[65] Hildebrandt and Story, 128-37.

Egyptian offensive and stifled any further advancement of aerial reconnaissance.[66] It would be almost half a century until aerial reconnaissance re-emerged as a potential asymmetric advantage in conflict, this time on the American continent.

The American Civil War gave rise to a resurgence in the use of aerial reconnaissance through ballooning, primarily by Union forces.[67] Observers used tethered balloons to communicate their surveillance results at all levels of war from the tactical to the strategic.[68] At the tactical and operational level, aerial observations assisted artillery in direct action and informed commanders of enemy troop activity.[69] Aerial reconnaissance assisted the strategic picture by relaying messages via telegraph, in some cases directly to the President to accurately inform him of an overall view of the battlefield.[70]

During the Franco-Prussian War, which followed soon after the American Civil War, military leaders on both sides began attempting to utilize aerial reconnaissance to gain relative advantage. Initially, the Germans used balloons at the front near Strasbourg and the French attempted the same after the fall of Sedan, but results were mixed at best.[71] Despite limited successes by the French Post Office to use balloons during the siege of Paris, aerial reconnaissance had not yet established itself as a fundamental element of warfare. These moderate results did not dismay the enthusiasts however, as the "possible value of military ballooning under favourable weather conditions was thoroughly recognised".[72] The scene was now set for aerial reconnaissance to dramatically improve. With camera technology improving and the aerial

[66] Hildebrandt and Story, 138.
[67] Civil War Trust, "Civil War Ballooning," Civil War Trust, 2014. http://www.civilwar.org/education/history/civil-war-ballooning/civil-war-ballooning.html. (accessed 12 April 2016)
[68] Hildebrandt and Story, 139.
[69] Trust, "Civil War Ballooning".
[70] Hildebrandt and Story, 139.
[71] Hildebrandt and Story, 142.
[72] Hildebrandt and Story, 150.

reconnaissance proof of concept complete, all that was needed was the airplane and the spark of war.

The Great War

> *Its first duty was reconnaissance. All its other and later uses were consequences of this central purpose, and were forced on it by the hard logic of events.*[73]
> Walter Raleigh
> RAF official historian

Wilbur and Orville Wright's invention of the airplane ignited a wave of enthusiasm for aviation throughout most of western Europe, and eventually on the American continent as well. The public was fascinated by "anything concerning aeronautics", for example drawing crowds of a million spectators to a 1909 airshow in Reims, France.[74] In addition to the airplane, a steerable version of the balloon, known generally as a dirigible, remained a credible option with civilian enthusiasts and military pioneers. The now infamous Zeppelin became a symbol of German strength, as well as an essential part of German military planning. By 1913 mission planning involving the Zeppelin featured as a critical component of German high command's strategic reconnaissance capability.[75]

The Advantages of Aerial Reconnaissance in WWI

However, by 1914, the airplane, rather than the balloon, had become the dominant form of military aircraft amongst the great powers, with hundreds now in national inventories where only a few years earlier

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[73] Walter Raleigh and Henry Albert Jones, *The War in the Air*, 6 vols., vol. 1 (Oxford,: The Clarendon press, 1922), 213.
[74] Lee B. Kennett, *The First Air War, 1914-1918* (New York: Free Press, 1991), 12.
[75] John Howard Morrow, *The Great War in the Air: Military Aviation from 1909 to 1921* (Tuscaloosa, Ala.: University of Alabama Press, 2009), 36.

there were none.[76] Aerial reconnaissance started to have an enormous impact on the very conduct of war, enabling accurate and deadly artillery as never before. Brigadier Jonathan Bailey, Director of Artillery for the British Army in 2001 describes the major military revolution of WWI as an 'Indirect-Fire Revolution,' thanks in large part to the technical advances in artillery coupled with aerial observation. As Bailey admits, it was air observation and photography that enabled precise targeting, with aerial mapping critical to maintaining an accurate ground picture of the trench systems.[77] Artillery or indirect fire were not new concepts in warfare, but the precision that aerial reconnaissance afforded had a fundamental impact on the conduct of the war. Aerial reconnaissance enabled scarce ammunition to be utilized more effectively, and creeping or rolling barrages in conjunction with ground force advances were made much safer. Accordingly, both the Allies and Germans underwent significant organizational restructuring in order to promote the command and control of artillery, including intelligence, planning and communication functions.[78] Aerial reconnaissance was shaping the ground war, the structure of military organizations, and providing tactical information to commanders, summarized well by this passage from the 1918 *Study and Exploitation of Aerial Photographs*:

> Aerial photography originated with trench warfare. It made rapid progress and had become one of the most important sources of information at the commander's disposal. In fact, it alone makes possible the exact location of the enemy's defensive works and their detailed study. Skillful camouflage, a large number of defenses and imitation works are some of the means employed. As a result, the study of aerial photographs must be entrusted to specialists,

[76] Kennett, 21.
[77] MacGregor Knox and Williamson Murray, *The Dynamics of Military Revolution, 1300-2050*, Kindle ed. (Cambridge, UK ; New York: Cambridge University Press, 2001), Location 3899.
[78] Knox and Murray, 3924.

> who should be provided with all possible means of verification.[79]

Risk vs Technology in WWI

The threat to aerial reconnaissance aircraft continued to mount as the war raged on. Without the ability to neutralize anti-aircraft sites, the solution for aviators was to fly higher, which in turn increased demand for higher quality cameras.[80] Reconnaissance airmen and camera engineers answered the call for better lenses, adjustable focal points, shutter speeds, and exposure options. By 1918, this increase in technology allowed the aerial reconnaissance units of most nations to achieve "excellent" imagery at altitudes up to 18,000 feet.[81] This trend of utilizing technology to mitigate risk is an important one that we will see repeated throughout this historical analysis.

By 1918, the aircraft had established itself as an essential tool of war for any great power, and the importance of aerial reconnaissance seemed beyond question.[82] The growth of the various air arms was staggering. The U.S Air Service for example, grew from 1,395 members upon entering the war to 195,024 by November 1918.[83] While the strategic value of aircraft was not fully exploited during the conflict, "politicians and generals such as Churchill, Ludendorff, and Pétain recognized the importance of airpower," including that brought by aerial reconnaissance.

> By the end of World War I, at least twenty-five percent of all the aircraft involved were used for photographic purposes. With the exception of the bombers, the majority of the other aircraft - pursuits - were used to gain air superiority and

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[79] Roy M. Stanley, *World War II Photo Intelligence* (New York: Scribner, 1981), 29.
[80] Grover Heiman, *Aerial Photography: The Story of Aerial Mapping and Reconnaissance*, Air Force Academy series (New York,: Macmillan, 1972), 42.
[81] Heiman, 42.
[82] Morrow, 36.
[83] Morrow, 36.

> protect the reconnaissance aircraft, whether they were engaged in taking photographs, doing visual observation, or directing artillery fire.[84]

The advent of more capable and mobile aerial reconnaissance also directly affected the risk and response of ground forces. Camouflage, which had remained largely static and two dimensional throughout the history of warfare, now had to adapt to this new threat from above.[85] Advancement on both sides of the battle, aerial reconnaissance vs camouflage, only heightened the need for more detailed and skilled photo interpretation.

Finally, improvements in communication, namely the wireless radio, greatly assisted both the effectiveness and survivability of aerial reconnaissance assets during WWI. Although the radio units were still very bulky, had poor range, and mostly used Morse code, they were still preferable to landing near the front or dropping written message in canisters that often ended up being lost in the confusion — and mud — of war.[86]

Aerial Reconnaissance Insights from the WWI era

Aerial reconnaissance proved itself not only critical, but extremely costly. With both sides understanding the advantages aerial reconnaissance provided and the vulnerabilities it exposed, offensive action against aerial reconnaissance capabilities was ruthless. The subsequent focus on providing either protection for, or pursuit against, aerial reconnaissance aircraft formed a substantial portion of the entire aviation war effort. When factoring in the cost of human life, it becomes clear that aerial reconnaissance was not a cheap enterprise in WWI.

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[84] Heiman, 41.
[85] Roy M Stanley, *To Fool a Glass Eye: Camouflage Versus Photoreconnaissance in World War II* (Smithsonian Institution Press, 1998), 11.
[86] Del Kostka, "Air Reconnaissance in World War One," 2011. http://www.militaryhistoryonline.com/wwi/articles/airreconinwwi.aspx#. (accessed 11 April 2016)

World War I also offers us a first glimpse of the relationship between technology and risk associated with aerial reconnaissance. Continued losses forced pilots of reconnaissance airplanes to higher and higher altitudes, but this technique was only possible through the continual improvement of aircraft design and camera technology of the day. Improved technology did yield a better reconnaissance product while also helping to save resources and keep reconnaissance crews alive.

The value of skilled photo interpretation was also a key lesson of WWI aerial reconnaissance. Teams of interpreters kept trench maps up-to-date as new photos came in while ground forces on both sides invented new ways to conceal their activities from the roving eyes and sensors in the sky.

A majority of historians agree the primary value of aerial reconnaissance during WWI was at the tactical level, although experimentation in the strategic use of air power surfaced in the closing stages and was subsequently heavily promoted by advocates such as Billy Mitchell and Giulio Douhet in the post-war years.[87] By 1918, senior political and military leadership, at least in Europe, appreciated the enormous benefits aerial reconnaissance provided to commanders.

[87] William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power -- Economic and Military* (Tuscaloosa, AL: University of Alabama Press, 2009).; Giulio Douhet, Joseph Patrick Harahan, and Richard H Kohn, *The Command of the Air* (University of Alabama Press, 2009).

Interwar Period

The British Experience

Despite the obvious advantages aerial reconnaissance offered during WWI, the newly formed RAF seemed reluctant to develop or even maintain this capability during the period of peace following the war.[88] Constance Babington-Smith, a renowned photo intelligence officer during WWII, suggested that the very tactical nature of aerial photography during WWI had resulted in some military minds assuming tactical reconnaissance was all it was good for.[89] "It is in the realm of aviation photography that our supremacy had been most conspicuous" declared a British Member of Parliament in 1919, no doubt referring to the 6.5 million photographs taken during the last year of the war.[90] The public sentiment for disarmament was extremely persuasive, however, and by 1938-39, the RAF realized it was completely unprepared for the demands of aerial photography beyond the trenches of WWI.

Luckily for the British, and indeed for all Allied efforts to come, aerial photography had not lain completely dormant in the civilian world. An enterprising Australian adventurer, Sidney "Sid" Cotton, had spent the 1930s developing aerial photographic techniques primarily as one of several business ventures. When the RAF approached Cotton for assistance in 1938, he quickly agreed, and the first serious long distance aerial reconnaissance missions took place before the outbreak of war. Using a civilian registered Lockheed 12A with extra fuel cells and a range of 1600 miles, Cotton could photograph a track almost 12 miles wide. In order to help the RAF build an up-to-date collection of maps as well as monitor German military presence, Cotton flew these routes on a regular

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88 Stanley, 36.

89 Constance Babington-Smith, *Air Spy: The Story of Photo Intelligence in World War II*, 1st ed. (New York,: Harper, 1957), 6.

90 Newhall, 55.

basis across mainland Europe, in and out of Germany and beyond. These clandestine operations continued right up until the declaration of war with Germany.[91] Despite the RAF still being significantly unprepared for wartime aerial reconnaissance, the Cotton operation was helping them catch up, and, more importantly, allowing them pre-conflict intelligence never before afforded to a nation so geographically separated.

The American Experience

Across the Atlantic, America was enduring a period of demilitarization following WWI, an economic downturn, and a strong public sentiment supporting isolationism.[92] Billy Mitchell, an avid supporter of airpower, was doing his best to promote investment and development of aircraft and associated tactics, which, owning to his involvement in WWI, included an understanding of the importance of aerial reconnaissance.[93] Unfortunately, only a few shared Mitchell's enthusiasm, as Brigadier General Goddard notes in his biography "no one in the Air Service gave a tin nickel for the advancement of aerial photography … while the U.S. Army cared about reconnaissance, it cared very little about reconnaissance from the air particularly when the war was over."[94] Mitchell and supporters attempted to stress the importance of thinking about future aerial reconnaissance capabilities, but Congress had no interest in spending defense money to bolster the current reconnaissance capability with no war to worry about. Thankfully, Congress did want to map many areas of the United States, so the government provided at least some funding for photo mapping in the 1920s and 1930s.[95]

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[91] Babington-Smith, 7-13.
[92] George W. Goddard and DeWitt S. Copp, *Overview: A Life-Long Adventure in Aerial Photography*, 1st ed. (Garden City, N.Y.: Doubleday, 1969), 18.
[93] Goddard and Copp, 21.
[94] Goddard and Copp, 21.
[95] Stanley, 32-6.

Without significant investment, however, photo interpretive skills dwindled within the U.S. military, and were it not for committed individuals such as the Lieutenant George Goddard, and a few skeleton photographic units, the situation may have been even worse when the United States eventually entered WWII.[96]

The German Experience

When the Luftwaffe reformed in 1933, their leadership was under no illusion about the importance of aerial photography. It is said that General von Fritsch, former Commander-in-Chief of the German Army "went so far as to forecast that the side with the best photographic reconnaissance would win the next war."[97] This statement would prove to be remarkably prophetic.

The Spanish Civil War provided the newly formed Luftwaffe with an opportunity to see aerial reconnaissance in action once again. Here they adopted more of a visual reconnaissance to directly support troops in contact and used photographs for deeper targets.[98] The tactical focus for aerial reconnaissance remained consistent for Germany as they entered WWII. The Wehrmacht was structured for relatively short range and direct support of their ground forces with aerial reconnaissance, and they failed to incorporate any significant strategic analysis of reconnaissance products until much later in the war against Russia.[99]

As in the United States, German officials recognized the utility of the aircraft to perform photo mapping. Prior to WWII, the Nazis put considerable resources into photo mapping ventures and were thus well

[96] United States Air Force, "Biography - Brigadier General George William Goddard," United States Air Force, 1987. http://www.af.mil/AboutUs/Biographies/Display/tabid/225/Article/106944/brigadier-general-george-william-goddard.aspx. (accessed 12 April 2016)
[97] Babington-Smith, 6.
[98] Stanley, 55.
[99] Stanley, 74.

well equipped to perform this role at the outbreak of war.[100] While the German's did have good reconnaissance aircraft and ground support for processing the photographic products capabilities, the short range of most of these aircraft limited their potential use for strategic reconnaissance against England or Russia.[101] The Fi 156 Storch, for example, had a range of only 600 miles, not even enough for a round trip from Cologne to London. Not unlike other Luftwaffe air assets, the Dornier 17F was excellent in 1937, but by 1939 it would be vulnerable and slow compared to new British fighters of the time.

Lessons of the Interwar Period

The major powers took very different lessons from the conclusion of WWI. The Allies, weary of conflict and yielding to public pressure for disarmament, chose not to pursue or fund any significant advancement in aerial reconnaissance. Thankfully the civilian sector did recognize the utility of the capability and kept development of airborne imagery alive.

Nothing breads success like failure, so it is no surprise that the Germans appreciated the role aerial reconnaissance played in their specific battlefield successes, yet ultimate loss of the Great War. At the outbreak of WWII, the German Luftwaffe were the best equipped and most prepared of all the major powers to perform and exploit aerial reconnaissance, albeit primarily in a tactical capacity. Though this situation did not persist for the entire war, the initial brutal successes of the German military campaign against France and England in 1938-1940 should serve as a warning against undervaluing aerial reconnaissance.

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[100] Stanley, 56.

[101] There is conjecture on this point, some arguing that a tactical 'army support' focus limited Luftwaffe reconnaissance, however Corum argues that it was a political leadership issue of the Third Reich to no think of England as an enemy until the last minute. Either way, Germany long range aerial reconnaissance and intelligence suffered. James S. Corum, *The Luftwaffe: Creating the Operational Air War, 1918-1940*, Modern war studies (Lawrence: University Press of Kansas, 1997), 283.

WWII

It is difficult to comprehensively cover the entire expansion, depth and impact of WWII aerial reconnaissance within a project of this size, such is the magnitude of the topic. However, there are snapshots of the war that are worth exploring in the context of this study. The following summary of aerial reconnaissance development and application aptly demonstrates some of the lessons gleaned from the WWII experience, many of which have applicability today. Rather than attempt to span every theatre of WWII, the following analysis will concentrate primarily on the European theatre as a representative crucible of the wider conflict.

1939-1942 — The RAF Relearn Aerial Reconnaissance

To highlight the aerial reconnaissance lessons of WWII, this paper will discuss the situation at the outbreak and early years of the war, and then compare it to the situation at the end of the war. As previously mentioned, the RAF's aerial reconnaissance capabilities had significantly atrophied during the interwar period.[102] While the Air Staff well understood the need for intelligence, they lacked the expertise and practice with which to obtain it. Immediately after the declaration of war in 1939 the RAF attempted to use Blenheim bombers for aerial reconnaissance against the German fleet at Wilhelmshaven, but the results were mixed at best.[103] Babington-Smith, a photographic interpreter during WWII describes how aerial reconnaissance was having an impact, in this case negatively: "The First Lord of the Admiralty, and indeed the Prime Minister himself, was most disturbed at the RAF's failure to photograph them [the targets] during the previous ten days."[104] The Blenheim squadrons had not prepared for reconnaissance under

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[102] Babington-Smith, 14.
[103] Babington-Smith, 13-4.
[104] Babington-Smith, 14.

war-time conditions, being vulnerable to the elements with camera lenses freezing even at moderate altitudes, as well as being vulnerable to German ground fire. Their losses were mounting.

Sid Cotton, the Australian civilian who had assisted greatly in the lead up to the war by covertly photographing many miles of continental Europe, offered to assist the RAF with its reconnaissance shortfalls. After initially finding resistance in the RAF bureaucracy, Cotton devised an unconventional way to convince the decision makers that his high altitude photography plan would work. The morning after a particularly unproductive meeting with RAF leadership, Cotton went flying in his Lockheed 12A, collecting imagery of the targets RAF reconnaissance had been completely unable to obtain. Furthermore, the high altitude approach ensured that Cotton achieved his reconnaissance flight without any enemy opposition.[105] This approach paid off, and before long, Cotton's outfit eventually became known as the Photographic Development Unit (PDU) and had four top-of-the-line Spitfire aircraft to use for aerial reconnaissance.[106] The advantage the Spitfire brought was speed and altitude, resulting in significantly reduced losses. A French intelligence officer keen to help Cotton and his Heston-based outfit, presented him in mid-January 1940 with compiled statistics for the war to date:

> The R.A.F. had photographed 2,500 square miles of enemy territory with a loss of 40 aircraft.
> The French had photographed 6,000 square miles of with a loss of 60 aircraft.
> The detachment from Heston had photographed 5,000 square miles without losing the one and only Spitfire that had done the whole job.[107]

[105] Babington-Smith, 16.
[106] Babington-Smith, 22.
[107] Babington-Smith, 34.

1943-1945 — Aerial Reconnaissance for Victory

With America and Japan now firmly ensconced in the war, aerial reconnaissance missions stretched from the Atlantic to the Pacific and from the deserts of Africa to the frozen tundra of Scandinavia.

The second half of the war was when aerial reconnaissance truly embedded itself as an irrefutably critical element of warfare. Divided into two main categories, tactical and strategic, it provided timely and essential information to planners around the clock.[108] So important was the provision of this intelligence that the Combined Bomber Offensive (CBO) would have been severely hamstrung without the detailed targeting information photo interpretation provided. As the Allied strategy moved toward one of strategic bombardment through the CBO, the collection of imagery the Allies were building proved invaluable for a number of utilities. By the latter half of the war, aerial photography was used to select bombing targets, determine bombing accuracy, assess bombing damage to facilities (BDA), determine enemy orders-of-battle, analyze equipment capability, pinpoint defense positions, facilitate map production of both enemy and friendly terrain, and identify enemy initiatives.[109] The mix of strategic and tactical reconnaissance, combined with first rate analysis, was proving to be the edge the allies needed to bring constant and relentless force to bear against the German war machine.

The 1944 Operation Overlord invasion and subsequent Battle of Normandy are key examples of how important aerial reconnaissance was to the overall war effort. For weeks prior to the invasion, Allied aircraft conducted high and low aerial reconnaissance to observe the landing sites and fortifications of the German forces.[110] By contrast, the

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[108] Roger Anthony Freeman, *The Mighty Eighth: Units, Men, and Machines: A History of the US 8th Air Force*, Rev. ed. (London: Jane's, 1986), 198.
[109] Stanley, 3.
[110] Paul Lashmar, *Spy Flights of the Cold War* (Annapolis, Md.: Naval Institute Press, 1996), 15.

Luftwaffe had almost completely lost its ability to perform aerial reconnaissance on mainland England and were often only successful when the Allies wanted to deceive them with fake invasion force details.[111] On the day of the landing, the first reliable information to head back to senior commanders in England was in the form of overhead aerial photography taken of the landing sites.[112] By this stage of the war, the aerial reconnaissance process was running so smoothly that photo interpreters could turn photo imagery around in less than two hours after landing. The improved speed of collection, analysis and distribution provided decision makers and field commanders a much more actionable intelligence product. Compared to WWI, the basic intent of aerial reconnaissance in WWII had not significantly changed, the end result was still to provide useful intelligence to the battlefield, however, the temporal aspect had made that intelligence much more effective.[113]

At the start of the war the allied forces initially downplayed the role of Tactical reconnaissance (TAC R), with only a very limited showing in the North African campaigns.[114] During 1944 and 1945, however, TAC R showed its real value as allied ground forces advanced eastward toward Germany. Operation Cobra was the United States Army offensive that occurred during the first few weeks after the Normandy landings, and TAC R support for the action was exemplary. TAC R exposed enemy positions and provided near instantaneous intelligence to commanders on the ground with direct communications. As General Patton rolled eastward across France, his forces were on the southern edge of the allied push and his desire for speed threatened to leave his right flank

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111 R. J. Overy, *The Air War, 1939-1945*, 1st Scarborough House trade paperback. ed. (Chelsea, MI: Scarborough House, 1991), 200.
112 Alfred Price, *Targeting the Reich: Allied Photographic Reconnaissance Over Europe, 1939-1945*, Military Book Club ed. (London: Greenhill, 2003), 121.
113 Dino A. Brugioni and Doris G. Taylor, *Eyes in the Sky: Eisenhower, the CIA, and Cold War Aerial Espionage* (Annapolis, Md.: Naval Institute Press, 2010), 23-4.
114 Robert Ehlers, *The Mediterranean Air War: Airpower and Allied Victory in World War II*, Modern war studies (Lawrence, Kan.: University Press of Kansas, 2015), 58.

exposed to German counter-attack. Patton demonstrated his faith in both the reconnaissance and tactical fighter aircraft, as he was confident that the U.S. Army Air Force "XIXth TAC would protect his flank."[115] The dynamic nature of mobile warfare called for a mix of visual and photographic flights, illustrating the depth of allied aerial reconnaissance by the end of the war.[116]

The Interpretation Dilemma

Without interpretation or analysis to generate intelligence, the direct output of aerial reconnaissance cannot be exploited. Early in WWII the lack of suitably trained interpreters was a significant problem for England and France, particularly the RAF, which in 1939 possessed only one "experienced photo-interpreter".[117] This situation changed relatively rapidly, as military leadership in England, France, and the United States started to recognize the benefits of skilled photo interpretation. By the mid-point of the war the allies possessed an extremely mature photo interpretation capability consisting of three phases.[118] The first phase occurred within hours of receiving photos after a reconnaissance run and concentrated on the movement of elements within the battlefield, the assessment of battle damage, and the identification of potential new targets.[119] The second phase usually occurred overnight and looked for more obscure detail as well as tying together the photographs from multiple reconnaissance runs into a coherent intelligence picture.[120] The final phase were more specialized and consisted of analysis that might be useful for strategic

[115] Thomas G. Ivie, *Aerial Reconnaissance: The 10th Photo Recon Group in World War II* (Fallbrook, CA: Aero Publishers, 1981), 67.
[116] Ivie, 67.
[117] Heiman, 80.
[118] Babington-Smith, 69.
[119] Heiman, 80.
[120] Heiman, 80.

considerations, such as civilian and military infrastructure, order of battle, and what is today often referred to as pattern-of-life analysis.[121]

Interestingly, the Axis powers were not as deliberate or organized when it came to photo interpretation, failing to capitalize on the advantages of centralized analysis of photographic products. The tactical and rapid mobility characteristics of the Wehrmacht were very effective during the initial years of the war, but the Luftwaffe did not adapt their aerial reconnaissance to the changing needs of the battlefield and eventually fell so far behind they could not compete with Allied fighter improvements and sophisticated Allied radar.[122]

The Role of Technology

Technology played a critical role in the advance of aerial reconnaissance in WWII. The Spitfire was a premium fighter when introduced for the reconnaissance role, able to fly above enemy fighter patrols. Later during the war the same could be said for the De Havilland Mosquito and P-38 Lightening twin-engine fighters, and of course, the infamous P-51 Mustang. Each of these aircraft was highly advanced for its era and enabled aerial reconnaissance to be conducted even over hostile territories.

Photography also continued to improve, particularly at high altitude with increases in clarity and reliability thanks to rapid camera development and the pioneers of new techniques. In 1939, George Goddard had discovered a technique originally designed for horse racing finish lines that would allow for the use of high speed cameras at low level later in the war.[123] The pursuit of these technologies, including other such developments as drop tanks, were intended not just to

[121] Heiman, 80.
[122] Overy, 199-200.
[123] Heiman, 74.

improve the product, but to raise the probability of survival, Similar to the evolution of reconnaissance during the First World War.

Lessons from WWII

> *You did some valuable work there. We used a lot of this photographic maps to good advantage. In fact we never could have won the war in the Pacific without aerial reconnaissance. You people made me a firm believer.*
>
> General MacArthur 1946

Richard Overy summarizes his one volume aerial history of WWII, *The Air War 1939-1945,* in his updated 2003 preface: "What air power did was create the conditions that made possible the success on land and sea; the absence of effective air power in Japan and Germany in the last year or so of war assured their defeat".[124] By the end of the war aerial reconnaissance had firmly established itself as a critical component of air power, from the tactical to strategic level. Intelligence gained through aerial reconnaissance provided a huge part of potency that enabled Allied success, and the ability to utilize a mix of tactical and strategic reconnaissance provided an asymmetric advantage over both German and Japan.

The advantage provided by aerial reconnaissance did not come easily, however, and both the Allies and Axis powers struggled at the beginning of the war to get back up to speed after a significant period of neglect. The Allies eventually prevailed, holding a resource advantage that was able to overcome the terrific resistance put up by the enemy. Had Allied commanders and statesmen recognized and resourced the reconnaissance capability earlier, many of the early losses might have been avoided.

Similar to the lessons of WWI however, aerial reconnaissance during WWII came at a heavy price in both resources and human life, one that authorities tolerated given the benefits it offered in such a desperate struggle. Toward the end of 1943, Air Marshall John Slessor,

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[124] Overy, xi.

Air Officer Commanding-in-Chief RAF Coastal Command, summarized the importance of the reconnaissance airman's sacrifice:

> The enormous extent to which we rely on this Wing for our knowledge of every aspect of the enemy's activity, is perhaps not generally realised; the science, not only of air photography but of interpretation, has made enormous strides in the last four years and the intelligence staffs would be blind without the courage and skill of the pilots and ground personnel of No. 106 Wing.[125]

Despite starting from a position of relative weakness, the Allied aerial reconnaissance efforts quickly identified high altitude reconnaissance as the most effective technique for the environment and pursued it relentlessly. Governmental momentum took some time to follow through with the appropriate resources, but when the support arrived it allowed units such as the PRU to thrive. In addition, the Allies realized the value of highly skilled photo interpretation and centralized analysis that could provide support not just at the tactical level, but up to the strategic level in support of the CBO or to provide information for political inquiry.

Insights From the 'First Thirty Years'

Military minds had conceived the advantages of aerial reconnaissance for many centuries, but it was the development of the balloon and later the camera that really kick started intellectual and development efforts in the late 19th century. By the outbreak of WWI, the airplane, balloon, and camera were beginning to form a coalescence of technology that would propel aerial reconnaissance from novelty to necessity in an incredibly short time.

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[125] Andrew Hendrie, *The Cinderella Service : RAF Coastal Command 1939-1945* (Barnsley, South Yorkshire: Pen & Sword Aviation, 2006), 187.

By the latter half of the war, it was clear aerial reconnaissance was so important to the war effort that it must be pursued actively even if the cost in human and materiel resources was extremely high. The desire for more detailed and rapid information, along with improved enemy concealment drove the need for improved camera, communication, and aircraft technology, which in turn allowed aerial reconnaissance crews to operate more safely and provide a better product.

The interwar period saw a dramatic drop in national will to invest in aerial reconnaissance, in large part as its application was still seen as tactical and tied directly to warfare. None of the major powers fully appreciated or invested in the peacetime or pre-conflict use of aerial reconnaissance, and it fell to civilian or domestic application to advance the cause. While Germany remembered the tactical use of aerial reconnaissance in WWI, and incorporated it into their Wehrmacht doctrine, they did not foresee or plan for the use of deeper strategic aerial reconnaissance. The lack of foresight during the interwar period caught all the Allies off guard at the outbreak of WWII, and it took England, France, and later the United States years to build the aerial reconnaissance force to the strength required for the conflict at hand.

As in WWI, aerial reconnaissance was a costly endeavor but one that simply had to be pursued. The Allies researched methods to protect reconnaissance crews and aircraft, and here, too, technology was used to offset risk in a meaningful way. The improvements in technology — aircraft, cameras, communications — had a dual role in improving the product and protecting the resources.

On a practical level, the intelligence organization behind WWII aerial reconnaissance proved to be just as critical as the raw product itself, and the Allied advantage in this area contributed significantly to the victory over Germany and Japan. The speed of communicating usable intelligence translated into direct battlefield advantage. Likewise, senior military and political leaders revered the ability to remain abreast

of the entire war dynamic and openly praised aerial reconnaissance for enabling the option. By 1945, aerial reconnaissance had shown its utility at all levels of war in all theaters, and was finally recognized by statesmen and commanders as a national strategic asset.

Chapter 4

Aerial Reconnaissance During the Cold War

> *Without intelligence you would have only your fears on which to plan your own defense arrangements and your whole country establishment. Now if you're going to use nothing but fear and that's all you have, you are going to make us an armed camp. So this kind of knowledge is vital to us.*[126]
>
> President Eisenhower, 1953

Aerial reconnaissance in the aftermath of WWII became a cacophony of projects, aircraft types, and organizations desperate for as much information as possible in the uncertain new world of East vs West. Within the major powers of the United States, Britain, France, and the USSR, leaders struggled to contextualize aerial reconnaissance in the absence of actual conflict.[127] Several new challenges to the aerial reconnaissance enterprise appeared that had been not been a concern during the two world wars. *Detection* became a real problem for western aerial reconnaissance, as radar technology improved and proliferated. Coupled with detection, the issue of accurate *navigation* became even more critical than ever before. Finally, *attribution* played a major role in international diplomacy as purveyors of aerial reconnaissance attempted to remain covert and non-provocative.

Although Cold War aerial reconnaissance introduces some new characteristics, most of the relevant lessons from the previous two world

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[126] Larry Tart and Robert Keefe, *The Price of Vigilance: Attacks on American Surveillance Flights*, 1st ed. (New York: Ballantine Books, 2001), 119.

[127] Both Truman and Eisenhower were very concerned with reconnaissance overflight of Russia and how it may affect relations as can be seen in various declassified Whitehouse memorandums. Likewise, Soviet leadership felt at times deeply vulnerable by Allied reconnaissance whilst also recognizing the need for intelligence collection. Tart and Keefe, 133.

wars still apply: aerial reconnaissance remained a costly enterprise and commanders must weigh risk against reward, reconnaissance professionals still searched for technical solutions wherever possible to improve the intelligence product, and there was an ongoing struggle to have aerial reconnaissance ready to meet the next challenge. This chapter will summarize the predominantly American development of aerial reconnaissance during this period, focusing on some expository examples such as recon during the Korean War and The Cuban Missile Crisis.

1945-1950

In the years preceding the 1950 kick off of the Korean War, the western powers grew increasingly concerned with maintaining security against the emerging threat that was Soviet Russia and the spread of communism.[128] Similar to WWII, aerial reconnaissance developed along two primary lines, strategic reconnaissance and tactical reconnaissance.[129] The push for strategic assets was understandably very strong in the wake of the atomic bomb, and with the formation of Strategic Air Command (SAC) in the United States and resource allocation winding down after the declaration of peace, tactical reconnaissance would take a back seat once again.[130]

In the late 1940s SAC reconnaissance aircraft set to work surveying, photographing, and mapping the arctic in search of strategically useful positions to be used against the USSR.[131] It was here that the issue of navigation first became a significant problem, with one reconnaissance aircraft flying 1500nm in the wrong direction due to the challenge of flying close to the poles.[132] Navigation discrepancy would

[128] Goddard and Copp, 349.
[129] Goddard and Copp, 363.
[130] Lashmar, 21.; Goddard and Copp, 363.
[131] Lashmar, 22.
[132] Lashmar, 26.

prove to have an ongoing influence on the aerial reconnaissance mission set, particularly with respect to diplomatic provocation and response.

As an illustration of the international tension of the time, General Curtis LeMay, then head of SAC, requested that SAC instigate a "pre-hostilities strategic overflight reconnaissance programme to warn against attack, and then a pre-emptive strike should follow," this proposal was rejected by the Chief of Air Staff.[133] In the Oval Office it seemed the President did not want to escalate tension, and in fact discussions in the US State Department at the time instead centered around how many miles reconnaissance aircraft should stand off of Eastern Bloc borders.[134] It was clear that the issue of respecting or violating borders was a heated topic between the government and the military.

Just before the outbreak of the Korean War came the first aerial reconnaissance fatalities when Russian fighters shot down a US Navy PB4Y-2 Privateer aircraft over the Baltic Sea.[135] This incident highlights themes that can follow through aerial reconnaissance history to the present day; *attribution* and *accountably*. By its very nature, aerial reconnaissance often requires the platform to be close to potential adversaries and far from friendly support. In these circumstances it is difficult to prove precisely what events did or did not take place, as was the case with the Navy Privateer in 1950. The Soviets claimed the aircraft had violated their territory, would not obey signals to land, and that the Privateer gunners had fired on the Soviet fighter interceptors.[136] American officials denied the aircraft was over Soviet territory and that it had a right to be in international airspace. While the issue was never fully resolved, what we do know is this and similar incidents of alleged sovereign incursion and subsequent aggression added significantly to

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133 Lashmar, 40.
134 Lashmar, 41.
135 Tart and Keefe, 16.
136 The Privateer was a flying boat still equipped with manned machine gun turrets. Tart and Keefe, 17.

already rising international tension. What is also known is that the United States did not suspend aerial reconnaissance missions, accepting instead the fact that no real alternative for gathering this kind of intelligence yet existed.

The Korean War

In June of 1950, Kim Il Sung of North Korea commanded his communist army to move south and take the entire Korean peninsula. The United Nations acted quickly and provided resolutions by which a U.S. military force could intervene and repel the presumptively Soviet backed attack.[137]

For the aerial reconnaissance assets of 1950, this new ground war presented quite a challenge. As previously mentioned, the tactical reconnaissance specialization of the newly formed US Air Force had not received much attention or funding since the end of WWII, just as in 1939, Allied forces found themselves playing catch-up. Early in the war as General MacArthur was planning the Inchon landing, General Goddard received a call from Chief of Air Force General Hoyt Vandenberg that summed up the situation succinctly: "George we're in bad shape in Korea. I've got a list of complaints from TAC as long as your nose. They say they don't have recce equipment. They don't have trained photointerpreters. I want you to get down here and explain why."[138] This was not an insurmountable problem, but a lack of forethought had convinced the USAF to place all their eggs in the strategic reconnaissance basket and they were now suffering as a result in this unexpected conflict. General George Goddard describes the challenges of aerial reconnaissance in Korea as being two-fold; first the terrain contained "high jagged mountains" unlike the majority of environments during WWII, and second, most of the reconnaissance had to be

[137] Lashmar, 48.
[138] Goddard and Copp, 368-9.

performed at night as this was the main time the North Koreans were active.[139] Once again the solution, or at least the mitigation, was technical in nature, as Project Red Light — a rapid development of night photography techniques and flash photography — did eventually assist in solving the night photo reconnaissance dilemma.[140]

TAC R also saw an injection of development thanks to furious spending back in the United States, Goddard describes it as being “like the beginning of World War II all over again.”[141] Low-level tactical reconnaissance aircraft acquitted themselves well in helping General Douglas MacArthur to prepare for his landing an Inchon, providing “tide heights, depths of reefs and measurements of sea walls on the selected landing beaches” that proved critical for invasion planning.[142] On the other hand, the process of developing, analyzing, and sending photographic interpretation results back to the front was extremely lacking. Heiman describes a situation where even after landing back in southern Japan, TAC R photographs could only be processed in Tokyo, a further three-hour flight, before being flown back to southern Japan for use by intelligence units, sometimes creating delays of almost a week in bad weather.[143] A capability honed to perfection only five years earlier had atrophied due to an almost exclusive focus on strategic reconnaissance. To add insult to injury for the tactical reconnaissance crews, one of the most highly recognized American reconnaissance pilots of WWII, Colonel Karl ‘Pop’ Prolifika was shot down and killed during a low-level reconnaissance flight over the peninsula.[144]

[139] Goddard and Copp, 372.
[140] Goddard and Copp, 373.
[141] Goddard and Copp, 370.
[142] Goddard and Copp, 375.
[143] Heiman, 112.
[144] Goddard and Copp, 375.

Korean War Insights

When the United States found itself on the brink of war in Korea in 1950 it was conditioned to think only of strategic long-range warfare with Russia. Aerial reconnaissance assets were accordingly focused on long-range strategic collection and ill-suited for the low level conventional and limited conflict that Korea present. Despite not being completely ready to collect it, the demand for aerial reconnaissance was immediate and unrelenting. The American tactical reconnaissance units had to quickly expand and adapt, a process that took time and undoubtable cost lives and resources.

Even with a capable overhead reconnaissance capability, ground and naval forces exhibited a significant demand for low-level, oblique and strip imagery, which would feed the intelligence required to plan and execute their respective missions. The perspective and clarity offered by this type of aerial reconnaissance provided planning and intelligence opportunities that high-altitude reconnaissance could not. Western militaries of today, more than 60 years after the Korean War, still have this precise requirement for detail that only medium- and low-level reconnaissance can provide.

In Korea aerial reconnaissance losses continued to be a factor, unsurprising in a combat zone but undesirable nonetheless. For the American administrations of the day, President Harry S. Truman then President Dwight D. Eisenhower, those losses were part of the cost of doing business. Dino Brugioni, a scholar with extensive experience in imagery analysis for the CIA, characterizes the Administration's primary concern with losses to be more about the aircraft and capabilities than about the crew members themselves.[145]

[145] Brugioni and Taylor, 71.

Eisenhower Expands Aerial Reconnaissance

From 1953, in the aftermath of the Korean War, America had a new president in Dwight D. Eisenhower, while at the same time Nikita Khrushchev became the effective head of state for the USSR following the death of Joseph Stalin. Eisenhower immediately recognized the need for ongoing aerial reconnaissance, having seen the benefits first hand as Supreme Allied Commander in Europe during WWII, and he pursued aerial reconnaissance aggressively over the following decade.[146] The Soviets remained highly cautious of American motivations, fearing aggression at every turn. Khrushchev in his memoirs notes:

> When Stalin died we felt terribly vulnerable . . . The Americans had the Soviet Union surrounded with military bases and kept sending reconnaissance planes deep into our territory, sometimes as far as Kiev. We expected and all-out attack any day.[147]

In the span of nine years, Eisenhower dealt with a series of crises and events on which he heavily relied on, and supported the use of, aerial reconnaissance. The ever present question of Soviet and Chinese military effectiveness loomed large over the Whitehouse and indeed US allies, such that Eisenhower knew he must have a solution with little-to-no attribution. In 1955, Eisenhower proposed the Open Skies program to the Soviet Union, allowing for mutually open aerial reconnaissance in the interest of transparency.[148] Despite a desire to decrease tension, the proposal met rejection and increased suspicion from the Soviet Union. Hedging against this possibility, Eisenhower had already approved plans

[146] Brugioni and Taylor, ix, 72-77.
[147] Tart and Keefe, 133.
[148] Robert A. McDonald, *Beyond Expectations: Building an American National Reconnaissance Capability: Recollections of the Pioneers and Founders of National Reconnaissance* (Bethesda, MD: American Society for Photogrammetry and Remote Sensing, 2002), 19.; Lashmar, 107.

for the CL-282, later known as the U-2, as a direct response to the perplexing question, what are the Russian's up to?[149]

The U-2 was originally thought to be undetectable, at least to the Soviet radars of the era, but that was an overly optimistic view which proved to be short lived. By 1956, detections were increasing and international tension was mounting. As Colonel Joe Santucci notes in his excellent dissertation *The Lens of Power: Aerial Reconnaissance and Diplomacy in the Airpower Century:* "From the end of World War II to 1953 (a period for which relatively accurate numbers are available), more than 250 cases of Soviet protests were logged with the State Department, the White House directly, or through the United Nations."[150] Despite initial skepticism by certain Air Force members, there was no questioning the product the U-2 was providing, in fact the intelligence it brought back from clandestine flights over communist territory confirmed to Eisenhower that there was no missile or bomber gap and no need for a costly arms race that might result in global disaster.[151]

1960 was milestone year for aerial reconnaissance. In January, the CIA gave Lockheed the go ahead to produce 12 test versions of their A-12 design, later known as the SR-71.[152] Five months later Captain Francis Gary Powers was shot down and captured while flying a U-2 reconnaissance mission on a scheduled mission into Soviet territory.[153] The Powers shoot-down, and subsequent public announcement by the Russians that he was alive, was an embarrassing revelation for the

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149 C. Pocock, *50 Years of the U-2: The Complete Illustrated History of the "Dragon Lady"* (Schiffer Military History, 2005), 17.; Lashmar, 138.

150 Joe Santucci, "The Lens of Power: Aerial Reconnaissance and Diplomacy in the Airpower Century," (Maxwell AFB, Alabama: School of Advanced Air and Space Studies, 2013), 102.

151 General Curtis LeMay, commander of SAC was famously quoted dismissing the concept of the U-2 by saying "This is a bunch of shit! I can do all that stuff with my B-36!" Pocock, 14, 43.

152 Paul F. Crickmore, *Lockheed SR-71: The Secret Missions Exposed*, Osprey Aerospace (London: Osprey, 1993), 11.

153 Dick van der Aart, *Aerial Espionage: Secret Intelligence Flights by East and West* (New York: Arco/Prentice Hall Press, 1986), 30-1.

Eisenhower administration and all U-2 overflights of the USSR ceased from that point.[154] The threat of escalation between two nuclear powers factored heavily in the President's decision not to continue the overflights, but the U-2 had proven the concept and validity of high-altitude penetration for reconnaissance purposes. As Eisenhower left office, the United States was only a few short years away from fielding the SR-71, an aerial reconnaissance aircraft that even by today's standards is an impressive piece of engineering.[155]

While this paper is primarily about aerial reconnaissance, it is worth mentioning that the end of the 1950s also marked a milestone for space operations. Another avenue the United States pursued in order to fill the intelligence hole was the idea of space-based reconnaissance satellites. It would be remiss to not mention the motivation gained from the news that the Soviets had succeeded in putting a satellite in orbit first with their 1957 launch of Sputnik. From 1956, the Defense Advanced Research Projects Agency (DARPA) and the Central Intelligence Agency (CIA) collaborated on the Discoverer program, partially a front for putting reconnaissance satellites in orbit covertly. In 1960 the program achieved the first successful drop of a film canister from the orbiting CORONA, and satellite reconnaissance was born.[156] (See Figure X)

Lessons From The Eisenhower Years

This era of bi-polar tension, ostensibly during peacetime, proved aerial reconnaissance could directly inform and impact diplomatic considerations. President Eisenhower recognized the utility of

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[154] Anthony M. Thornborough, *Sky Spies: Three Decades of Airborne Reconnaissance* (London
New York, NY: Arms and Armour Press ;
Distributed in the USA by Sterling Pub. Co., 1993), 12.
[155] Aart, 32.
[156] DARPA, "Reconnaissance Satellite," Arlington, VA: DoD. http://www.darpa.mil/about-us/timeline/reconnaissance-satellite. (accessed 16 May 2016)

reconnaissance from his wartime experience, but quickly found it also played a very important new role in international relations.

From providing information during the Suez crisis to disproving the myth of the the bomber gap, the capable U-2 proved invaluable to national security. While overflight eventually became politically undesirable due to improved Soviet radar and surface-to-air missiles, the value of high-altitude aerial reconnaissance was confirmed.

The fledgling satellite reconnaissance capability started with CORONA appeared to offer a way to achieve overhead reconnaissance without attribution or risk. For statesmen and commanders alike, the promise of gaining intelligence without suffering losses and remaining clandestine is very alluring. It is hardly surprising then that satellite reconnaissance received significant support over the past half century to morph into the impressive, predominately American controlled, capability in use today.[157]

The Cuban Missile Crisis

On the 14 of October 1962, Maj Steve Heyser took off from California and flew his CIA operated U-2 on mission 3101 over the western portion of Cuba, remaining over Cuban soil for only seven minutes in order to capture his footage, before finally landing safely in Florida. The film was couriered to Washington for processing and analysis by the National Photo Interpretation Center (NPIC), who by the next day had determined there were suspicious looking canvas covered objects in the imagery. The following day, NPIC subsequently identified the objects as SS-4 medium-range intercontinental ballistic missiles. By

[157] McDonald, 75.

the 16th, President Kennedy was being briefed in the White House where he simply said, "How long have we got?"[158]

Of note, mission 3101 was originally approved for 9 October, but poor weather precluded the high-altitude aircraft from launching until five days later.[159] This limitation was soon offset as the US Navy and Marine Corps introduced low-altitude fast-jet reconnaissance flights, which were to prove critical in building the intelligence picture. Kenneth Jack emphasized in a 2012 speech, while referring to low-level photographs of Russian missile sites on Cuba: "This is another example of the superior detail quality of the low-level photographs. These were the types of photographs that really gave President Kennedy the means to gauge how operational the missiles were. It gave him time to give Cruzchev time to think about the crisis he had started."[160]

Despite excellent results by both the high flying CIA U-2s and low level US Navy and Marine Corps RF—8 Crusaders, not all aerial reconnaissance went smoothly over Cuba. The USAF brought their RF-101C Voodoo TAC reconnaissance variants, but in a situation not too dissimilar to the start of the Korean conflict, a lack of training and investment in the TAC R role had left their skills, sensor equipment, and photo interpretation capability wanting.[161] Dino Brugioni describes the essence of the shortfall after Navy cameras had been fitted to the USAF aircraft:

> Not only were Air Force cameras and pilot training lacking, its PIs were poorly trained and understaffed. When, at last, interpretable

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[158] Wayne H. Whitten, Chris Pocock, and Kenneth V. Jack, *Aerial Reconnaissance During the Cuban Missle Crisis*, *Panel presentation for American HistoryTV* (Washington D.C.2012).
[159] Whitten, Pocock, and Jack, *Aerial Reconnaissance During the Cuban Missle Crisis*.
[160] Whitten, Pocock, and Jack, *Aerial Reconnaissance During the Cuban Missle Crisis*.
[161] William B. Ecker and Kenneth V. Jack, *Blue Moon Over Cuba: Aerial Reconnaissance During the Cuban Missile Crisis* (Oxford ; Long Island City, NY: Osprey Publishing, 2012), 116-7.

> imagery was received, Gen Walter Sweeney, the TAC commander, hurried over to see it. He asked the TAC major in charge to point out the missiles on the film. Reyes Ponce, and expert SAC interpreter [who accompanied Sweeney], was flabbergasted. Finally, he could resist no long, "Sir, what the major is showing you is a fallen palm tree."[162]

The dire nature of the situation during the 13 days of the Cuban missile crisis needs little amplification, however, the focus on aerial reconnaissance as a major tool of both diplomacy and military effort is remarkable.[163]

In one short incident, the crisis utilized three different reconnaissance variants. Initially the NRO tried CORONA with its Keyhole cameras, although it proved to be inadequately developed at this early stage of development. The U-2 performed its signature clandestine high-altitude reconnaissance and provided the first indication of a problem, although weather prevented high-level operations from providing all the necessary intelligence. Finally, low-level high-speed reconnaissance provided images of increased clarity albeit at increased risk. The detailed low-level images enabled decision makers, such as President Kennedy, to finally take stock of the situation. Had only one of those options been available, it seems unlikely all the pieces of the intelligence puzzle would have come together in the way they did.

Even as satellite imagery started to improve in leaps and bounds through the 1960s, 1970s, and 1980s, aerial reconnaissance continued to play a fundamentally pivotal role in providing decision makers with timely, detailed, and contextual intelligence from perspectives that satellites could not always achieve. In Vietnam, for example, the triple

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[162] Dino A. Brugioni and Robert F. McCort, *Eyeball to Eyeball: The Inside Story of the Cuban Missile Crisis*, 1st ed. (New York: Random House, 1991), 444.
[163] Brugioni's *Eyeball to Eyeball* is an excellent retelling of events with a focus on aerial reconnaissance and the importance of that intelligence on informing diplomatic discourse.

layer canopies of the southeast Asian jungles challenged the predominately strategic aerial reconnaissance assets of the USAF.[164] As a result, tactical reconnaissance was once again pressed into service, and the dawn of the unmanned aerial vehicle began.[165]

Cold War Lessons

The 1950s and 1960s were an incredibly tense time for the United States and its allies as they struggled to understand what was occurring behind the Iron Curtain, balancing intelligence collecting aerial reconnaissance needs with nuclear fueled international tension. By the end of the 1950s, talented engineers, with the support of a reconnaissance minded president, had developed and implemented one solution in the form of the U-2 and were on the way to an even more advanced intelligence collector with the SR-71. No matter the outcome, the delay between recognition of the problem and execution must have felt like an eternity. Eisenhower recognized the absolute necessity to conduct reconnaissance on the Soviet Union, and he was also acutely aware of the potential diplomatic ramifications of being *detected* while doing so.[166] Aerial reconnaissance had a significant impact on diplomacy in the relative peace post-WWII, Korea and Vietnam notwithstanding, and continued to prove critical to decision makers seeking intelligence on the environments.

Like aerial reconnaissance before it, the Cold War proved that there is a cost to intelligence collection. Losses hit home as hard as ever, with hundreds of airman missing, not to mention the destruction or capture of valuable reconnaissance equipment by adversaries. A new

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164 Bernard C. Nalty, *Air War over South Vietnam, 1968-1975* (Washington, D.C.: Air Force History and Museums Program, 2000), 90.
165 Thomas P Ehrhard, *Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation* (Johns Hopkins University, 2000), 499.
166 Colonel A.J. Goodpaster, "Memoranda for the Record: Reconnaissance Projects and Possible Tracking by Soviets," ed. Office of the Staff Secretary (Washington, D.C.1956).

loss crept into the Cold War, too, a loss of face. The 1950 shoot-down of a US Navy Privateer and the 1960 Gary Powers incident illustrate the diplomatic ramifications of aerial reconnaissance during peacetime. The development of GPS to aid in precise *navigation*, or stealth technology to avoid *detection* today have as much to do with avoiding *attribution* as they do avoiding losses. Given the importance of accurate navigation in reconnaissance missions, it is important to ask how much have we come to rely on space to achieve those goals.

The United States in particular used technology to mitigate risk rather than adopt a game of attrition, both by reducing the risk to the aerial reconnaissance mission itself, and also by using the intelligence gained to build a far more accurate picture of the global chessboard. As in WWI and WWII, reconnaissance aircraft increasing elevation above the threats worked for a while, but eventually that advantage started to diminish. The parallels with satellites, the highest of all the platforms, should not be lost here. Altitude also has limitations on the usefulness of the intelligence product, while high-altitude reconnaissance is excellent for broad coverage, there is an increased level of detail and alternate perspective that lower altitude reconnaissance delivers. The contemporary obsession with UAV imagery confirms that regardless of high-altitude image fidelity, the low-level product continues to be in high demand from commanders and statesmen.

Chapter 5

Preparing For The Possibility

Gulf War Reactions

For most people, the fall of the Berlin Wall, the collapse of the Soviet Union, and the American-led UN victory in the Persian Gulf War marked a significant turning point in history. For the many in the military, the Persian Gulf War represented the 'first space war.' GPS allowed unrivaled precision in navigation and timing; early warning satellites detected missile launches to warn against Saddam's SCUDs; weather satellites provided land, sea, and air forces with accurate forecasts; and communications satellites allowed commanders and statesmen around the world to keep track of the war in real time.[167] When Secretary of Defense Dick Cheney prepared the 150-page *Annual Report to the President and the Congress*, much was made of the advantage space assets had brought during the Gulf War. Nowhere does the report mention a potential weakness in American space power, on the contrary; the direct assertion is one of offensive advantage: "During a conflict, if significant military space capability is available to an adversary, anti-satellite (ASAT), operations may be necessary. DoD's ongoing ASAT program, which would provide a deployed kinetic energy ASAT weapon around the year 2000, could effectively negate an adversary's capability to target U.S. and allied forces from space."[168]

Paul Crickmore provides an alternative perspective in his 1997 compendium on the controversially retired SR-71. Crickmore claims that "[d]uring the Persian Gulf War, our commanders on the scene badly needed the capabilities of the SR—71." Furthermore "the fact is that the

[167] Dick Cheney, "Annual Report to the President and the Congress," (DTIC Document, 1992), 85-91.
[168] Cheney, "Annual Report to the President and the Congress," 85-91.

SR—71 could have mapped Iraq in three hours and provided intelligence that was not available to the United States planners for the duration of the conflict."[169]

The Gulf War marks a very distinct point in time where not only did the United States demonstrate an asymmetric advantage in military hardware and war fighting doctrine, but it also enjoyed an advantage having transitioned to an increasingly information centric organization. As described in the opening chapters, space-based assets such as GPS, communication, and reconnaissance satellites have enabled the transition to this "information warfare" model, and aerial reconnaissance, or ISR, has embraced the model completely.[170]

Conclusion

This thesis has attempted to bring together two schools of knowledge. Those involved in collecting, processing, or using ISR are generally quite familiar with the aerial reconnaissance concepts covered in this paper. The second school of knowledge is that of the far rarer space professional. The pros and cons of space laid out here will shock none of these readers. It is more likely the unclassified nature of the discussion may have even frustrated them. The vulnerabilities laid out in Chapter 2, whilst very real, have impelled experts in the space field to actively pursue solutions, as are many vested partners in the civilian sector. When it comes to space consumers, however, there is a good-to-fair chance that most ISR providers or patrons do not stop to think about the link to space, nor its vulnerability. If the lessons of the past 100 years have anything to add to this discussion, it is that a lack of preparedness will not reduce the demand for aerial reconnaissance, and will only cost time, resources, and human lives to rectify. By not

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[169] Crickmore, 86-7.
[170] Keith L. Shimko, *The Iraq Wars and America's Military Revolution* (New York, NY: Cambridge University Press, 2010), 9, 139, 64.

thinking about the problem, or even recognizing its existence, those charged with conducting aerial reconnaissance and providing the subsequent intelligence product cannot hope to cope well should space be compromised.

The ultimate aim of bringing these two fields of knowledge together is to add to the growing chorus of voices that wishes to acknowledge that the problem of space vulnerability is not just that of the space professional. While the commander of an ISR squadron may not be responsible for communication or GPS satellites being jammed, they will be responsible if they cannot perform their mission because there is no redundancy built into their operations. A recent paper by a career USAF Intelligence officer with operational experience in Iraq, Afghanistan, and Africa illustrates the dilemma: "Although the concepts of ISR as we know it have been in place for centuries, the speed at which information is processed and required on the battlefield today, along with the vast quantity of ISR available, resembles nothing in the past."[171] The author highlights two important differences that space has added to our ISR or aerial reconnaissance product, speed and reliability. These factors do give western militaries an edge in combat, and in peacetime, but if their availability is underwritten by space-based assets, how will they respond when access to those assets is compromised? Again, the intelligence officer has some excellent insight: "Commanders from all services have become reliant on ISR professionals to find, fix, and track targets; indeed, without reliable ISR, many commanders will not execute operations."[172] The dependence western militaries now have on either satellite reconnaissance or satellite dependent aerial reconnaissance is a

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[171] Adam B. Captain Young, "Employing Intelligence, Surveillance, and Reconnaissance: Organizing, Training, and Equipping to Get It Right," *Air & Space Power Journal* (2014): 41, http://www.au.af.mil/au/afri/aspj/digital/pdf/articles/2014-Jan-Feb/F-Young.pdf.
[172] Captain Young, "Employing Intelligence, Surveillance, and Reconnaissance: Organizing, Training, and Equipping to Get It Right," 41.

troubling reality, not least because not once in this 2014 article entitled *Employing Intelligence, Surveillance, and Reconnaissance: Organizing, Training, and Equipping to Get It Right* is the dependence on space-based assets nor their vulnerabilities addressed. The intent of this exposé is not to single out the author of that particular article. In fact, the somewhat blind faith the ISR fraternity has in space just 'being available' is demonstrably widespread, and the major motivation for writing this paper in the first place.

In order to prepare for aerial reconnaissance in a space-denied environment, there are some lessons that purveyors of aerial reconnaissance can take away from the past 100 years. Listed below are the major themes that emerged during this paper's analysis.

Technical Solutions

This study has highlighted a consistent trend with aerial reconnaissance, the application of technology in order to mitigate a threat and reduce risk. The space vulnerability dilemma proposed in this paper is different because the threat is far less obvious than in the past, and often not acknowledged as a vulnerability by the aerial reconnaissance community. Below are some examples of technical innovation that might provide some solutions to aerial reconnaissance in a space-denied environment:

A Royal Australian Air Force strategic project known as Project Jericho is working on several concepts including one that is trailing wide-band data communications over high-frequency radio. This communication method would reduce Australian military dependency on satellite relays and is openly designed to offer a sovereign solution to one portion of space vulnerabilities.[173]

[173] Australian Aviation, "ADF Trials Data Transfer Under Plan Jericho," Phantom Media, 2015. http://australianaviation.com.au/2015/10/adf-trials-data-transfer-under-plan-jericho/. (accessed 23 May 2016)

In the United States, DARPA is also looking at a way to “exchange massive amounts of data that are used to produce situational awareness and guide decision-making” because “satellite Communications (SATCOM) services can provide some capacity to remote areas but cannot provide the capacity needed to support the amount of data generated by emerging ISR systems.”[174]

To provide redundancy for GPS, DARPA is also working on Adaptable Navigation Systems which would provide GPS like accuracy through Precision Inertial Navigation Systems and All Source Positioning and Navigation which utilizes sources alternate to GPS to correlate fixes.[175]

These solutions are encouraging and appear to be on the right track to mitigate the vulnerability of space, however, it is likely any widespread implementation of these technical solutions are years, if not decades, away.

Preparedness

At the start of WWI, commanders recognized the need for reconnaissance-driven intelligence, but were initially unprepared to deal with the advances aerial reconnaissance provided. In WWII both the UK and United States failed to capitalize on the lessons of the last war and were initially unprepared to conduct aerial reconnaissance under hostile conditions, or process the results into a useable timely intelligence product. In the Korean War the USAF was unprepared to conduct tactical or low-level reconnaissance as this skill had been neglected in favor of long-range strategic reconnaissance, nor where they ready to process the results quickly at the battlefield level.

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174 Ted Dr. Woodward, "100 Gb/s RF Backbone (100G)," Arlington, VA: DoD. http://www.darpa.mil/about-us/timeline/reconnaissance-satellite. (accessed 23 May 2016)

175 Haas, "Adaptable Navigation Systems (ANS)".

Preparedness today means achieving the aerial reconnaissance mission, high, low, deep or tactical, and being able to do it with little or no access to space. Preparedness today also means being ready for the possibility of increased losses, should the stand-off ranges afforded by space be unavailable. Preparedness also means political leadership must be prepared to deal with increased tensions that increase aerial reconnaissance is likely to create. A difficult challenge for commanders, but one that they should remain mindful of if overflight or border violations become *de rigueur* in lieu of space-based sensors.

Redundancy

The Cuban Missile Crisis aptly demonstrated, by good planning or good luck, the benefits of redundancy in aerial reconnaissance. The new CORONA satellite reconnaissance platform was unable to deliver the necessary product; the U-2 provided a good product, but was frequently hampered by weather and reduced image quality; the low level TAC R jets provided higher risk yet higher reward coverage yielding excellent intelligence. Having multiple aerial reconnaissance options proved essential to the outcome the crisis. It is also worth noting that because image processing and intelligence systems of the era were not reliant on high-speed world-wide satellite communications, decision makers were accustomed to working with delays in receiving intelligence.

Today redundancy primarily means navigation and communications and control. It is, in actuality, more complicated than that, but given that most of what goes to and from a satellite in support of aerial reconnaissance are communications or position updates, it makes sense to concentrate on these first. Only an estimated 5% of the world's telecommunication traffic travel by satellite, with the remaining 95% utilizing subsea cable networks. Does it makes sense to look to

cyber as a potential redundant answer to our satellite woes?[176] Given the constantly increasing capacity and redundant pathways that already exist to hold the internet together, terrestrial-based cyber networks may indeed be an excellent and relatively cheap backup to satellite communications, although not without significant security challenges of its own that need to be met.

Despite the apparent gloom this security dilemma poses, the United States and its allies should not abandon the many advantages space-based assets bring to battlefield or national security. Instead, they must hedge against the potential threats in order to maintain an advantage, no matter the circumstances. Promoting a short term solution to enable space-independent aerial reconnaissance is by no means an advocacy for reducing work on solving the vulnerabilities of space, or suitable terrestrial redundancies. The issues raised in this paper will almost certainly require a multi-pronged approach, and, with a problem so complex and globally intertwined, the more options available the better. In essence, there is not yet a silver bullet for the aerial reconnaissance dilemma the West has collectively created, but there are definitely improvements that can be made in the short term without significant investment.

Detailing how each unit, aircraft type, mission set, or intelligence agency might achieve the goals mentioned above is well beyond the scope of this investigation. The answers, thankfully, are buried in the collective minds of the thousands of service men and women in the United States and amongst her allies. Ideally, senior military leaders in a position to influence the *raise, train, and sustain* functions of their Services, Groups, Departments, and organizations should carefully consider the questions raised in this study and at least have a framework by which their unit

[176] David E Sanger and Eric Schmitt, "Russian Ships Near Data Cables Are Too Close for U.S. Comfort," *The New York Times*, 25 October 2015.

might function without space.[177] By leveraging on the evidence of past success in aerial reconnaissance, leadership needs to enable our talented pool of military professionals to acknowledge the problem of space dependence and work on tactics, techniques, and procedures to overcome the challenge with the tools we already have.

Not unlike other uncomfortable problems that tend to lay buried, acknowledgement of the issue is an important step in seeking a solution. If General John Hyten, Commander of Air Force Space Command is willing to openly discuss the threats that exist to space and the need to address them, so should those who most depend on it.[178]

[177] Raise, Train, Sustain (RTS) is the Australian Defense Force equivalent of the U.S. Organize, Train and Equip: Strategic Policy Division, "The Strategic Framework 2010," (Canberra, Australia2010), 31.

[178] John General Hyten, "Reinventing Space: Increasing Awareness, Decreasing Vulnerability" (paper presented at the 2015 Air and Space Conference, 2015).

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